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Human Exposure to Atmospheric Concentration of Selected Chemicals. Volume I

Systems Applications, Inc.
San Rafael, CA

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

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SAI

Human Exposure To Atmospheric Concentrations Of Selected Chemicals

Volume I

Office of Air Quality Planning and Standards
Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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16. ABSTRACT

Population exposure was estimated for 29 selected chemicals or groups of chemicals emitted into the ambient air. The exposure assessments identify types and locations of sources of air pollution; estimate emissions, ambient concentrations, and surrounding populations; and provide rough order-of-magnitude estimates of the number of people exposed to various concentrations of the individual chemicals on a nationwide basis.

This study was performed by Systems Applications, Incorporated, under the sponsorship of the U.S. Environmental Protection Agency. The work was completed as of May 1980.

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SAI HUMAN EXPOSURE TO ATMOSPHERIC CONCENTRATIONS OF SELECTED CHEMICALS

ERRATA SHEET

Values for the reaction rate constants found on page 73 of the SAI Report "Human Exposure to Atmospheric Concentrations of Selected Chemicals" were used to estimate population exposure for 21 of the 35 chemicals evaluated. The computer program used to estimate population exposure requires reaction rate constants to be calculated on a decay per second basis. However, the values presented on page 73 were specified in decay per minute units. In some cases, this error resulted in an underestimation of exposure and dosage estimates by as much as a factor of ten. Corrected factors for the affected chemicals follow:

Acetaldehyde	$7.3 \times 10^{-5}\ \text{sec}^{-1}$
Acrolein	$1.6 \times 10^{-4}\ \text{sec}^{-1}$, $5.0 \times 10^{-6}\ \text{sec}^{-1}$
Allyl Chloride	$3.0 \times 10^{-5}\ \text{sec}^{-1}$, $1.5 \times 10^{-6}\ \text{sec}^{-1}$
Benzyl chloride	$2.8 \times 10^{-5}\ \text{sec}^{-1}$
Chlorobenzene	$4.67 \times 10^{-6}\ \text{sec}^{-1}$
Chloroprene	$7.6 \times 10^{-5}\ \text{sec}^{-1}$, $2.0 \times 10^{-5}\ \text{sec}^{-1}$
m-Cresol	$1.68 \times 10^{-4}\ \text{sec}^{-1}$, $1.0 \times 10^{-6}\ \text{sec}^{-1}$
p-Cresol	$1.41 \times 10^{-4}\ \text{sec}^{-1}$, $1.0 \times 10^{-6}\ \text{sec}^{-1}$
o-Cresol	$1.41 \times 10^{-4}\ \text{sec}^{-1}$, $1.0 \times 10^{-6}\ \text{sec}^{-1}$
o-Dichlorobenzene	$7.5 \times 10^{-6}\ \text{sec}^{-1}$, $5.0 \times 10^{-7}\ \text{sec}^{-1}$
p-Dichlorobenzene	$7.5 \times 10^{-6}\ \text{sec}^{-1}$, $5.0 \times 10^{-7}\ \text{sec}^{-1}$
Ethylene Oxide	$1.4 \times 10^{-5}\ \text{sec}^{-1}$
Formaldehyde	$4.2 \times 10^{-5}\ \text{sec}^{-1}$
PCB	$7.0 \times 10^{-5}\ \text{sec}^{-1}$
Phenol	$2.95 \times 10^{-5}\ \text{sec}^{-1}$, $1.5 \times 10^{-6}\ \text{sec}^{-1}$
Propylene Oxide	$1.4 \times 10^{-5}\ \text{sec}^{-1}$
Toluene	$2.8 \times 10^{-5}\ \text{sec}^{-1}$
Trichloroethylene	$2.8 \times 10^{-5}\ \text{sec}^{-1}$
m-Xylene	$1.12 \times 10^{-4}\ \text{sec}^{-1}$
p-Xylene	$1.12 \times 10^{-4}\ \text{sec}^{-1}$
o-Xylene	$5.6 \times 10^{-5}\ \text{sec}^{-1}$

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SECTION 1

EXECUTIVE SUMMARY

INTRODUCTION

Recent federal legislation has responded to the increased public awareness of and concern about the public health danger of man-made chemicals in the environment. These laws have, in turn, placed more responsibility on the Environmental Protection Agency (EPA) to assess the need for regulatory control over the sources of these chemicals. Assessment of the need for additional control requires information about the chemicals, their interaction with the environment, and their health impacts on the human population. As part of a continuing effort by the EPA to fulfill this information need, the Strategies and Air Standards Division of the EPA's Office of Air Quality Planning and Standards has commissioned the study of human exposures to atmospheric concentrations of selected chemicals that is reported here.

Chemicals such as those analyzed in this program are subject to control through several different legal and regulatory mechanisms. However, regardless of the regulatory approach that is utilized, issues pertaining to the health effects of the chemicals indicate the need for development of the following information:

- > Quantities of pollutants emitted
- > Population at risk
- > Chemical and physical properties of the chemicals
- > Danger to public health.

Thus, in support of the primary goal of estimating human exposure to the given chemicals, it was necessary to quantify emissions of the chemicals and to estimate the chemical and physical properties of the substances.

This study of human exposure to certain chemicals is one element of a health risk assessment. Health risk depends on:

> The effect on human health of exposure to a pollutant
> The patterns of pollutant concentration
> The human population exposed to the pollutant patterns.

Since this program does not address the development or use of a health effects model, it is not known what population factors (e.g., age, sex, occupation, racial background), environmental factors (e.g., climate, diet, chemical reactions), and exposure factors (e.g., duration and dosage of exposure, concentration threshold, concentration level) are important. Accordingly, the methodologies developed for use in our study are designed to accommodate the quantification of such effects in future studies.

The results of this study are expressed in terms of both the human population exposed to different concentration levels of each substance and the dosage potential (here called dosage) for the exposed population. As used in this program, exposure is the number of people whose breathing space contains the given pollutant at a specified concentration. Dosage is not the quantity absorbed by human bodies, but for this program merely the potential dosage measured by a concentration multiplied by the number of people exposed. Both exposure and dosage are presented in annual terms.

THE STRUCTURE OF THE STUDY TEAM

The study of human exposure and dosage to atmospheric concentrations of the selected chemicals involves three major aspects, which may be formulated in terms of "what, where, and who" questions:

> What material is released to the atmosphere?
> Where does the material go?
> Who receives the material at the places it reaches?

Each of these three program elements was addressed by a specific study group:

> Systems Applications, Incorporated (SAI)--SAI managed the program and developed and carried out all transport and dispersion analyses (where); defined and executed the exposure/dosage computations (who); and undertook all auxiliary studies, such as the species monographs, reactivity studies, etc.
> Hydroscience, Incorporated (HI)--HI performed all emissions work (what), determining the locations, processes, emission characteristics, and emission rates of all sources of the studied pollutants.
> Minimax Research Corporation (MRC)--MRC created the population data file (who) and the computer program used to interpolate population concentration data and calculate exposure-dosage.

The Principal Investigator of the program was Gerald Anderson of SAI, and the SAI program associate manager was Chung Liu. Hoi-Ying Holman (SAI) carried out the programming of the "matrix modeling." The associate manager for emissions studies was Dwight Erickson of HI, and the associate manager for exposure/dosage software was Dr. Carlos Puig of MRC.

Until September, 1979, the project manager for the EPA's Strategies and Standards Division (SASD) was Richard Johnson; after a reorganization of SASD, project management was the responsibility of Dr. Nancy Pate.

STUDIED CHEMICALS

Early in the program study period, the EPA presented a list of 41 chemicals to be assessed in this study. Subsequently, the following six chemicals were deleted from the list under EPA instructions:

- Acetylene tetrachloride
- Bischloromethyl ether (BCME)
- Chloromethyl methyl ether (CMME)
- Methyl iodide
- 1-naphthylamine
- 2-nitropropane.

Acetylene tetrachloride and 1-naphthylamine were deleted from the list because preliminary review of available information indicated that neither chemical is any longer produced or used in the United States. CMME is an intermediate created and consumed captively in the manufacture of ion exchange resins. BCME is an impurity also created with CMME. Available information indicated that BCME and CMME are totally consumed when the reaction to form ion exchange resin is completed. The only potential emissions source of either of these chemicals is through an emergency vent of the reactor at some time when one or both of the chemicals is present. Methyl iodide is an extremely small-volume specialty chemical with an estimated annual production of 50,000 pounds. Emissions from production and use as a reagent would be negligible. The IMC Corporation plant, located at Sterlington, Lousiana, is the only chemical plant that produces 2-nitropropane. This chemical is another small-volume specialty chemical. State air emissions files indicate that no 2-nitropropane emissions results from its production.

Table 1 is a complete list of the remaining 35 chemicals. Emissions data were estimated for all of them, with the exceptions of dimethylnitrosamine and nitrosomorpholine. These two nitroso compounds are formed in the atmosphere as the result of reaction between nitrous acid and amines (Hanst et al., 1977), so emissions data for their corresponding precursors, dimethylamine and morpholine, were estimated instead.

HEALTH RISK ANALYSIS

The human exposure analysis conducted in this study is part of a health risk analysis for atmospheric pollutants. The latter is based on the concept that adverse physiological changes may be produced in human tissue that has contacted or absorbed some airborne material. The change might depend--at least statistically--on some characteristic of the individual (e.g., age, sex, occupation, racial background), on the complete time pattern of the pollutant received (amount of dosage received over exposed* time), and on any measure of that pattern. Pollutant patterns can be measured in several ways:

- > Total dosage.
- > Dosage in a given time.
- > Exposure at or above a given dose rate.
- > Linear or nonlinear and continuous or noncontinuous functions of any of the above measures.

---

* Exposure is the occurrence of contact between human and pollutants. Dose is the total amount of material received. In this report, the concentration to which a person is exposed on an average annual basis is a measure of the potential dose he may receive. This quantity, summed over all exposed persons, is referred to here as dosage.

TABLE 1. LIST OF CHEMICALS FOR HUMAN EXPOSURE/DOSAGE ESTIMATION

No.	Chemical
1	Acetaldehyde
2	Acrolein
3	Allyl chloride
4	Benzyl chloride
5	Beryllium
6	Carbon tetrachloride
7	Chlorobenzene (mono)
8	Chloroform
9	Chloroprene
10	m-Cresol
11	o-Cresol
12	p-Cresol
13	o-Dichlorobenzene
14	p-Dichlorobenzene
15	Dimethylnitrosamine
16	2,3,7,8-TCDD (dioxin)
17	Epichlorohydrin
18	Ethylene oxide
19	Formaldehyde
20	Hexachlorocyclopentadiene
21	Manganese
22	Methylene chloride
23	Nitrosomorpholine
24	Nickel
25	Nitrobenzene
26	PCBs
27	Phenol
28	Phosgene
29	Propylene oxide
30	Toluene
31	1,1,1-Trichloroethane
32	Trichloroethylene
33	m-Xylene
34	o-Xylene
35	p-Xylene

Determining the health risk of a person requires knowledge of the coefficients of dependence on factors such as those listed above. Providing the inputs required for a health risk analysis, then, must include identification of the following:

- > A health effect as a function of characteristics of the exposed person and of a pattern of exposure to an airborne chemical.
- > Emissions sources and emissions rates of the chemical.
- > The dispersive environment of the source.
- > The chemical and physical properties of the chemical in the ambient air.
- > The population distribution patterns, stratified by identifying characteristics, that are subject to the influence of the sources.

Three general tasks are required to convert these inputs to a health risk assessment:

- > Estimation of concentration patterns of the pollutant in time and space.
- > Computation of the appropriate measure of the concentration patterns.
- > Summation of the product of the concentration pattern measure, the health effect coefficients, and the population in each class over space and time.

The limitation of the focus of this study to human exposure rather than health risk eliminates the necessity of having to identify a health effect function. However, appropriate methods of exposure analysis depend on the form of the health effect function. The function must be presumed to depend on some function of the time history of concentration to which a person is exposed. Even statistical bases for identifying health effects functions are usually weak; therefore, the health effect functions used in practice typically are based on the simplest possible measures of a concentration pattern. The two simplest measures are exposure and dosage.

Exposure is generally related to a given concentration level. This type of model is applicable to reversible health effects. That is, below the "standard" concentration, the body can repair damage rapidly enough to suppress symptoms. As the standard is exceeded, the human body becomes less capable of repairing damage at a satisfactory rate. Thus, damage symptoms appear in more and more people. All of the so-called criteria pollutants subject to National Ambient Air Quality Standards (NAAQS) are presumed to produce reversible effects at NAAQS levels. The NAAQS themselves are exposure types of standards. Of course, sufficiently high exposure to such pollutants can produce irreversible organ damage or death.

Some pollutants can produce irreversible cell or genetic damage or irreversible cancerous consequences at very low concentrations. Because of the irreversibility of such effects, the total damage to the body can depend on the accumulation of such events and thus on the pollutant dosage that the body receives. If such damage is sustained at very low levels, it may well be generally undetectable, yet its cumulative or randomly critical nature may create an unacceptable health risk to the total population. Some bodily damage may be reversible or inconsequential at low levels of exposure or dosage but irreversible at higher levels. Such behavior is referred to as "threshold" variation.

It is presumed that the effect of carcinogenic materials is to produce critical cell damage. Thus, carcinogenic health effects models generally are dose (i.e., integrated exposure) models, not exposure models. The lack of firm statistical bases often leads to the adoption of nonthreshold, linear models, even though thresholds and nonlinear effects might be expected.

If linear (dose) models without thresholds are to be used for carcinogen (or other) risk assessment, estimation of exposure at specified levels becomes irrelevant or, at least, nonintuitive. For example, a carcinogen risk analysis may be based on a linear, nonthreshold health effects model. The total health risk would thus be proportional to the long-term exposure summed for all affected people for the identified period. Exposure of many people at low concentrations would be equivalent to exposure of a few to high concentrations. The atmospheric dispersion that reduces concentrations would also lead to exposure of more people; therefore, increments to population risk would not necessarily diminish with increasing dispersion time or distance. Limits to human risk would exist only if the concentration or population patterns were bounded. Since the model does not exclude background concentrations from global transport, bounding of the concentration patterns by either chemical decay or scavenging by such phenomena as precipitation and respiration would be necessary for legitimate analysis by a linear, nonthreshold model. However, arbitrary boundary limits (e.g., 20 km for specific point sources) were set for this purpose.

In spite of this argument, a linear health effects model was assumed in this study. It is not practical to determine the time history of exposure for a single person or for all the population as a whole in this study, so the annual average exposure levels were estimated. Population exposure was defined in this study as the number of people exposed to annual average concentrations of ambient chemical no less than certain exposure levels. Dosage was defined as the product of population and concentration (at no less than certain levels) to which they would be exposed. Therefore, both exposure and dosage are functions of exposure level.

A time factor has been built into both exposure and dosage. Since the health risk is proportional to the long-term exposed concentration under the linear assumption, annual population exposure should be a good estimate of the number of people with a given level of health risk, and dosage should be a good indication of risk involved at a given level of ambient concentration.

SOURCES AND EMISSIONS

The list of chemicals presented in Table 1 contains materials of quite disparate character. Distinctive characteristics include the following:

> Phase--Solids, liquids, and gases (at ambient conditions) are represented.

> Chemical Reactivity--Some are nonreactive; some decay by atmospheric chemical processes; and some are created by such processes.

> Ubiquity--Some are widely distributed; others are found in isolated locations, isolated times, or both.

> Mode of emission--In general, when a pollutant is exposed to the atmosphere some fraction is lost to the atmosphere. Since each material is handled differently, it enters the air by a different mode. Some identified modes are
> - Evaporation from open surface.
> - Emission through a stack.
> - Emission through a vent (a vent is not designed to elevate the emitted material; a stack is).
> - Leaks in plumbing or storage containers.
> - Wind-blown dust.

> Emission rate--Rates range from minute to massive.

> Proximity to people--Materials are emitted from sites of varying remoteness.

Because of the number of characteristics that must be addressed, three different methods were used for estimating concentration patterns, one method for each of three categories of sources. The three source categories are

- Major, specific point sources--These consist of individually identified sources, usually a manufacturing plant. Such sources have known locations and modes and rates of emission. Each accounts for a significant fraction of the national emissions of some species.
- Other point sources--Sources that are too numerous, small, or of uncertain location, and yet produce isolated patterns of significant concentration, are not treated specifically. Rather, a prototype of such sources is defined, and the results of prototype analysis are multiplied by estimated numbers of sources that the prototype represents. Degreasers are an example of sources that were treated by prototype.
- Area Source--Sources that are so numerous and emit so little that patterns of concentration are analyzed only "en masse." Such sources include both stationary (e.g., home chimneys) and mobile (e.g., automobiles) types. Emission rates per unit area are estimated; emission modes are not addressed.

Emission rates, modes, locations, and times were described for each species studied. The emission work was done by Hydroscience, Incorporated (HI), of Knoxville, Tennessee. Emissions characterization involved review of trade literature, files of the various states, EPA reports and data, and site visits and correspondence with staff of specific sources.

The results of this program include the completion of emissions summaries that identify source locations and estimate the total nationwide emissions of the 35 chemicals. These summaries are included in the attached species reports. Further description of the emission estimation process is given in Section 2. Rankings of the studied chemicals and their sources by emission rate are given at the end of this section on pages 21 to 32.

DISPERSION MODELING

The estimation of human exposure/dosage to atmospheric concentrations of the studied chemicals involved three computational tasks:

- Estimation of annual average concentration patterns of each chemical on the region about each source.
- Estimation of the population pattern over the area of each computed concentration pattern..
- Computation of sums of products of the concentration and population patterns to provide exposure/dosage estimates.

Concentration Patterns

The large number of chemicals and sources that were modeled in this program would consume large computer resources if conventional modeling systems had been used. To keep computer costs within reasonable bounds while ensuring that the computing effort would meet program needs, we developed a combined "reactive prototype" and "matrix" modeling system.

The estimation of concentration patterns was done with a different approach for each of the three source types described above.

- Specific point sources
- Prototype point sources
- Area sources.

Each of these types of sources requires a different modeling approach. In addition, the concentrations of some of the selected chemicals depend on reactions in large-scale plumes of photoreactive materials from urban regions or industrial complexes. Although SAI has developed and used many types of photochemical simulation models, application of such models to the number and variety of sources studied in the present program would require large labor and funding resources; hence, these models were not recommended for this program.

MAJOR (SPECIFIC) POINT SOURCES

Major sources of most of the selected chemicals are specifically identified chemical manufacturing plants. Concentration patterns due to unit emissions from such sources depend most strongly on several factors:

> Source elevation above terrain
> Wind vectors (speed and direction)
> Dispersive effects (intensity of atmospheric turbulence).

Long-term average concentrations depend on the time histories of the meteorological parameters. A useful simplification that greatly reduces computational requirements is the computation of long-term average concentrations by taking climatological weighted sums of concentrations computed for a set of discrete states of the atmosphere. This approach is used in the EPA's climatological dispersion models, AQDM and CDM; for each state of the atmosphere, these models compute Gaussian dispersion patterns. The annual average concentration pattern is then computed as a weighted summation of the patterns for each atmospheric state. AQDM and CDM are designed for application to urban regional problems with large inventories of sources. The EPA's point source models, PTMAX, PTDIS, PTMTP, and CRS, also use a Gaussian kernel, but are designed for estimating short-term (one-hour to one-day) average concentrations. The approach used to develop long-term average concentrations in the EPA's benzene exposure study (Mara and Lee, 1978) was to compute one-hour results and to infer annual averages by using assumed time-averaging period scaling factors.

In the present study, the computations were carried out taking into account the following source-specific factors:

- > Climatological data from nearest or otherwise most appropriate recording station.
- > Individual treatment of releases from each identified process or vent within a plant.
- > Release height, speed, and buoyancy.
- > Effects of wakes from nearby structures.
- > Diurnal variations of emissions.
- > Seasonal variations of emissions.
- > Urban or rural character of area.
- > Atmospheric chemical reaction after release of emissions.

GENERAL POINT SOURCES REPRESENTED BY PROTOTYPE

Some point sources are not treated individually because of their number and emissions strength; such sources are too numerous, their emissions are too small to warrant individual modeling, or both. Unlike area sources, these sources are separated widely enough that their patterns of pollution impact do not generally overlap. In lieu of the individual modeling of each such source, a prototype source is defined to represent each such source; dispersion and exposure/dosage patterns are computed for the prototype; and results are multiplied by the number of sources the prototype represents.

Such sources were modeled using the matrix model for unit emissions rates rather than emissions rates for actual, specifically identified sources. When appropriate, prototype sources were analyzed for each region of the country using meteorological data representative of that region. The nine geographic regions in the United States (see Figure 1) are used here, and a model source would be defined for each generic source category in each of the nine regions.

AREA SOURCES

Area sources of either a selected chemical or a precursor present a common problem for modeling. In particular, the rich and complex patterns of hydrocarbon emissions from general urban and industrial sources either include or might produce through atmospheric photochemical reactions some of the species on the analysis list. The treatment of such species in photochemical airshed modeling is difficult (Anderson et al., 1977; Tesche and Burton, 1978). The effort required for any one such exercise is substantial, and the effort required for a comprehensive analysis of all urban regions relevant to this program would be prohibitive.

We have treated reactive effects through judicious scaling of nonreactive results by factors developed by photochemical "prototype" definitions. Nonreactive modeling of area sources was carried out by use of a box model (Hanna, 1973). This type of model can be used to treat general, undifferentiated source densities in an urban region. Box model results for each wind speed and stability, weighted by climatological probabilities, were used to compute long-term averages.

Basic box models cannot portray effects of nonuniform source patterns. If, for particular chemical species or particular source classes, the dependence of emissions on population density or other identifiable parameters is apparent and significant, we have used modifications to the box model approach. As an example, it might be assumed in modeling products of combustion of the lighter fuel oil distillates that source distribution patterns are proportional to population density patterns, because most of such fuel is burned in residential furnaces in cold-weather cities.

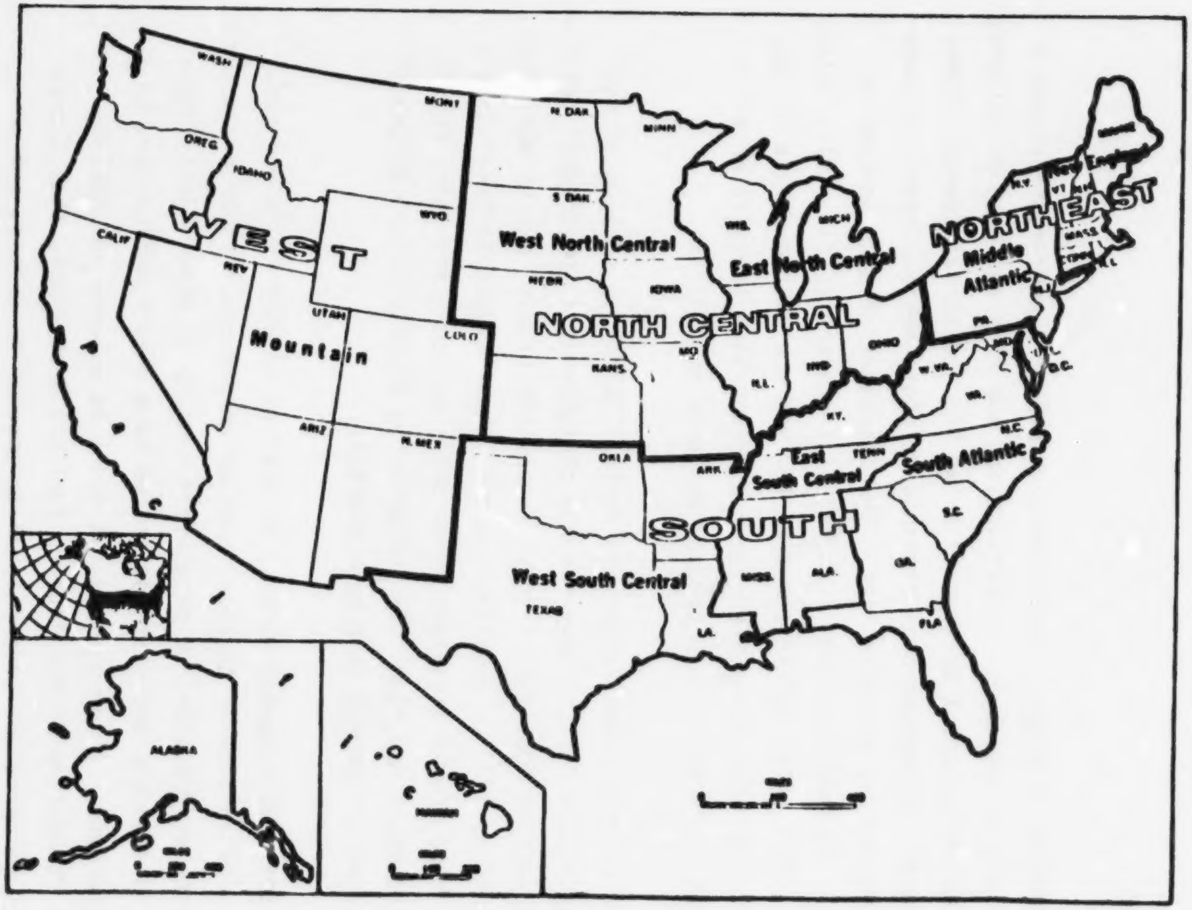
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FIGURE 1. U.S. GEOGRAPHIC REGIONS

Where possible, we have addressed dispersion modeling requirements by using models that

- > Are specific to source type
- > Are specific to site
- > Address relevant physical and chemical phenomena
- > Address relevant time and space scales
- > Are based on EPA-recommended algorithms
- > Are computationally efficient.

More extensive descriptions of the dispersion modeling methods used are presented in Section 3.

POPULATION MODELING

Population modeling was also done using different methods for each of the three types of sources:

- > Major, specific point sources
- > Prototype point sources
- > Area sources.

For major point sources, site-specific population patterns were extracted from U.S. Census Bureau files using data at the Enumeration District/Block Group (ED/BG) level. These data provide the finest resolution of population patterns available. The data were scaled from 1970 to a base year of 1978. Interpolations of population and concentration patterns were used to develop patterns of exposure/dosage that were then summed to produce source-specific exposure/dosage totals.

The same dispersion procedures were used for modeling of other point sources, but, since only prototype sources were addressed, population data were required only for prototypical conditions in each geographic region. Prototypical population was represented by the average population density in the urbanized areas of each region.

For area sources, only city-average population density and area were used for each city so modeled.

Extensive descriptions of these techniques are presented in Section 3. Further description of the population data bases is given in Section 2.

RESULTS

Twenty-nine reports are presented as attachments to this report. Each report summarizes, for a single species, the following:

- > Emissions sources, including number, identification, and location of sources of each type.
- > Emission and rate modes.
- > A table of physical and chemical data.
- > Tables of concentration, exposure, and dosage for each source and source type, and total exposure and dosage.

The emissions study identified and provided computations of the concentration, exposure, and dosage patterns for the following:

- > There were 311 major chemical manufacturing or consuming plants covered in this study. Because some major chemical plants were involved in more than one chemical, specific point source modeling was applied for 538 plants. Since there may be more than one source type in a plant, dispersion-dosage modeling was conducted for a total of 1819 individual point sources in this study.

> There were 62 source categories involved in the prototype modeling, each with nine regions. Hence, the prototype point source modeling was conducted for a total of 558 prototype sources.

> Gaussian dispersion model computations were made for all "Urbanized Areas" (248) for each of the 77 area source categories, for a total of 19,096 runs.

> Gaussian dispersion model computations were made for all other cities (243) with a population over 25,000 for each of the 77 area source categories, for a total of 18,711 runs.

> Box model computations were made for 150 cities with populations between 2,500 and 25,000 for each of the 77 area source categories, for a total of 11,550 runs.

In total, emission estimates and dispersion, population, and exposure/dosage computations were made for 51,734 cases.

In Table 2 the 35 chemicals are ranked by their 1978 nationwide emissions. Table 3 lists the 20 sites that emitted the greatest quantitites of the 35 chemicals in 1978. A detailed breakdown of emissions from these 20 chemical plants is also given. Figure 2 displays sources that emit more than 10,000 pounds per year of these chemicals; a complete list of specific point sources of these 35 chemicals is included in Attachment A.

Similar rankings of the 35 chemicals by their dosage potential to the national total population are presented in Table 4, and the 20 sites producing the greatest dosage potential of all studied chemicals combined are presented in Table 5.

An extensive review of the uncertainties associated with these estimates is presented in Section 4.

TABLE 2. RANK ORDER LISTING OF STUDIED CHEMICALS BY TOTAL EMISSIONS

Rank	Chemical	Chemical Abstract Service Registry No.	Total Emissions[*] (lb/yr)
1	Toluene	108-88-3	2,235,842,590
2	1,1,1-Trichloroethane	71-55-6	538,730,000
3	m-Xylene	108-38-3	453,533,940
4	Methylene chloride	75-09-2	407,700,000
5	o-Xylene	45-47-6	268,497,360
6	Trichloroethylene	79-01-6	240,700,000
7	p-Xylene	106-42-3	239,270,414
8	Chlorobenzene	108-90-7	175,376,130
9	Carbon tetrachloride	56-23-5	65,030,000
10	p-Dichlorobenzene	95-50-1	49,900,950
11	Manganese	7439-96-5	35,000,000
12	Formaldehyde	50-00-0	33,000,000
13	Chloroform	67-66-3	24,040,000
14	Nickel	7440-02-0	22,573,640
15	o-Dichlorobenzene	95-50-1	15,269,450
16	Nitrobenzene	98-95-2	13,040,000
17	m-Cresol[†]	108-39-4	10,960,000
18	Morpholine	110-91-8	10,028,000
19	p-Cresol	106-44-5	9,124,941
20	Phenol	108-95-2	6,924,360
21	Acetaldehyde	75-07-0	4,853,950
22	o-Cresol	95-48-7	4,504,150
23	Chloroprene	126-99-8	3,523,092
24	Ethylene oxide	75-21-8	1,991,000
25	Propylene oxide	75-56-9	1,346,160
26	Allyl chloride	107-05-1	1,110,000
27	Epichlorohydrin	106-89-8	479,000
28	Beryllium	744-04-17	357,035
29	Phosgene	75-44-5	253,176
30	Dimethylamine[§]	124-40-3	215,400
31	Acrolein	107-02-8	102,920
32	Benzyl chloride	100-44-7	100,271
33	Hexachlorocyclopentadiene	77-47-4	59,500
34	PCBs	11097-69-1; 11096-82-5	30,020
35	2,3,7,8 TCDD-(dioxin)	828-00-2	84

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[*] Actual emissions estimated as of 1978. See attached species reports.

[†] Emitted precursor to atmospheric formation of nitrosomorpholine.

[§] Emitted precursor to atmospheric formation of dimethylnitrosoamine.

Source: Species emissions summaries by Hydroscience, Incorporated, Knoxville, Tennessee included in attached species reports.

TABLE 3. RANK ORDER LISTING OF THE TOP TWENTY SITES BY TOTAL EMISSIONS WITH INDIVIDUAL CHEMICAL CONTRIBUTION

Rank	Company/Location	Chemical	Individual Emissions Contribution (lb/yr)	Total Emissions (lb/yr)
1.	Dow/Freeport, TX	Propylene oxide	577,700	
		Phenol	826,720	
		o-Dichlorobenzene	1,118,010	
		1,1,1-Trichloroethane	226,200	
		Mixed xylenes	30,400	
		Allyl chloride	539,120	
		Epichlorohydrin	170,740	
		Phosgene	18,450	
		Toluene	300,560	
		Ethylene oxide	176,000	
		Methylene chloride	185,880	
		Chloroform	30,230	
		Carbon tetrachloride	14,280	
		Trichloroethylene	184,400	
				4,438,760
2.	Amoco/Decatur, AL	p-Xylene		3,896,400
3.	Celanese/Bishop, TX	Formaldehyde	292,800	
		Acetaldehyde	3,294,800	
				3,587,600
4.	Du Pont/Laplace, LA	Chloroprene	2,541,678	
		Toluene	679,294	
				3,220,972
5.	Hercules/Hopewell, VA	Nitrobenzene		2,263,125
6.	FMC/S. Charleston, WV	Carbon tetrachloride		2,184,000

TABLE 3 (Continued)

Rank	Company/Location	Chemical	Individual Emissions Contribution (lb/yr)	Total Emissions (lb/yr)
7.	Dow/Plaquemine, LA	Nitrobenzene	567,375	
		Methylene chloride	331,410	
		Chloroform	78,690	
		Carbon tetrachloride	140,950	
		Ethylene oxide	192,000	
		Propylene oxide	174,160	
		1,1,1-Trichloroethane	638,400	
				2,122,985
8.	Shell/Deer Park, TX	Phenol	884,440	
		Mixed xylenes	59,880	
		o-Xylene	367,200	
		p-Xylene	125,600	
		Allyl chloride	259,490	
		Epichlorohydrin	89,030	
		Toluene	190,800	
				1,976,440
9.	BASF Wyandotte/Geismar, LA	Phosgene	8,190	
		Ethylene oxide	121,000	
		o-Dichlorobenzene	1,118,010	
		Formaldehyde	270,000	
		Propylene oxide	5,880	
		Toluene	70,400	
				1,593,480

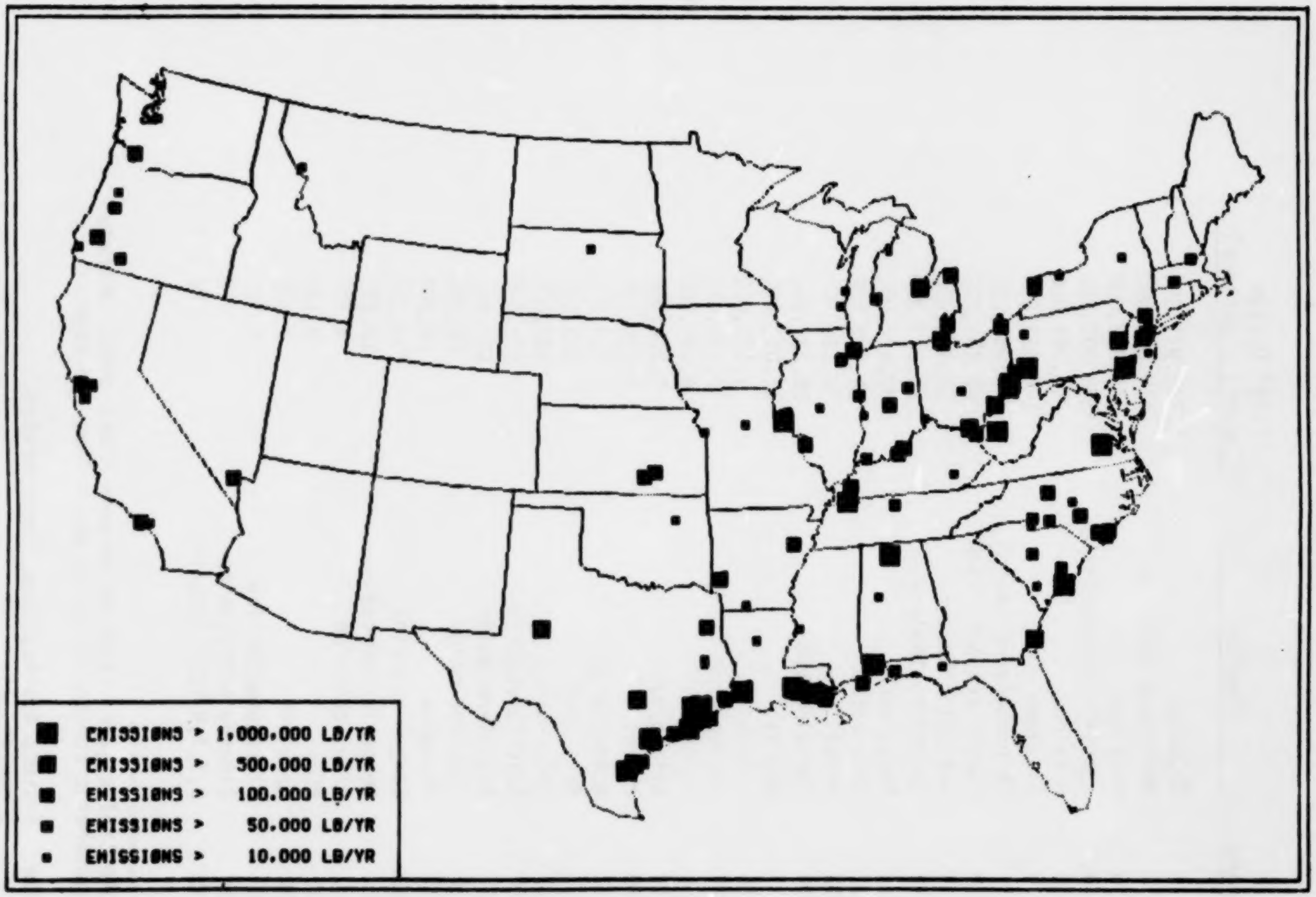
TABLE 3 (Continued)

Rank Company/Location	Chemical	Individual Emissions Contribution (lb/yr)	Total Emissions (lb/yr)
10. Mobay/Baytown, TX	Phosgene	35,548	
	Toluene	90,880	
	o-Dichlorobenzene	1,453,416	
	Propylene oxide	5,880	
			1,585,724
11. Tennessee Eastman/ Kingsport, TN	Acetaldehyde	1,416,810	
	p-Xylene	57,270	
			1,474,080
12. Celanese/Clear Lake, TX	Acetaldehyde	1,281,360	
	Acrolein	5,965	
	Ethylene oxide	185,300	
			1,472,625
13. Stauffer/Lemoyne, AL	Carbon tetrachloride		1,456,000
14. Amoco/Texas City, TX	Mixed xylenes	140,520	
	m-Xylene	176,000	
	p-Xylene	1,034,630	
	Toluene	19,760	
			1,370,910
15. Mobay/New Martinsville, WV	Phenol	28,400	
	Phosgene	35,086	
	o-Dichlorobenzene	1,118,010	
	Propylene oxide	4,660	
	Toluene	70,400	
			1,256,556

TABLE 3 (Concluded)

Rank Company/Location	Chemical	Individual Emissions Contribution (lb/yr)	Total Emissions (lb/yr)
16. Olin/Lake Charles, LA	Phosgene	17,082	
	o-Dichlorobenzene	1,118,010	
	Propylene oxide	1,840	
	Toluene	70,400	
			1,207,332
17. Amoco/Cooper River, SC	p-Xylene		1,199,520
18. Du Pont/Deepwater, NJ	Nitrobenzene	1,275	
	Phosgene	18,934	
	Chlorobenzene	68,650	
	Carbon tetrachloride	75,420	
	Chloroform	148,800	
	Toluene	48,640	
	o-Dichlorobenzene	782,610	
			1,144,329
19. Hercules/Louisiana, MO	Formaldehyde	899,500	
	Acetaldehyde	130,600	
			1,030,100
20. Allied/Moundsville, WV	Phosgene	14,214	
	Methyl chloride	89,440	
	Chloroform	22,640	
	Carbon tetrachloride	820	
	o-Dichlorobenzene	894,410	
	Toluene	56,320	
			1,077,844

Source: Species emissions summaries by Hydroscience, Incorporated, Knoxville, Tennessee; included in attached species reports.


EMISSIONS > 1,000,000 LB/YR
EMISSIONS > 500,000 LB/YR
EMISSIONS > 100,000 LB/YR
EMISSIONS > 50,000 LB/YR
EMISSIONS > 10,000 LB/YR

Source: Species emission reports were made by Hydroscience, Incorporated, Knoxville, Tennessee, and are included in the attached species reports.

FIGURE 2. SPECIFIC CHEMICAL-EMITTING POINT SOURCES

TABLE 4. STUDIED CHEMICALS RANKED BY ESTIMATED TOTAL U.S. DOSAGE*

Ranking	Chemical	Total Dosage [(μg/m^3) persons]
1	Toluene	1,748,971,000
2	Methylene chloride	410,800,000
3	m-Xylene	348,852,000
4	1,1,1-Trichloroethane	338,000,000
5	o-Xylene	216,759,000
6	p-Xylene	174,532,800
7	Chlorobenzene (mono)	73,059,100
8	Carbon tetrachloride	68,806,200
9	p-Dichlorobenzene	51,430,000
10	Trichloroethylene	34,523,000
11	Manganese	30,420,000
12	Chloroform	24,729,508
13	Nickel	16,669,800
14	Formaldehyde	16,197,800
15	m-Cresol	11,012,000
16	p-Cresol	9,185,000
17	o-Dichlorobenzene	7,238,000
18	o-Cresol	4,485,000
19	Nitrobenzene	2,774,000
20	Phenol	1,028,300
21	Acetaldehyde	469,000
22	Beryllium	219,600
23	Chloroprene	188,000
24	Epichlorohydrin	177,400
25	Propylene oxide	107,930
26	Ethylene oxide	78,200
27	Phosgene	26,300
28	Benzyl chloride	19,180
29	Hexachloropentadiene	19,100
30	Allyl chloride	9,770
31	PCBs	9,130
32	Acrolein	7,380
33	Nitrosomorpholine	6,900
34	Dimethylnitrosamine	620
35	2,3,7,8-TCDD (dioxin)	76

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* Potential dosage: Exposed persons times annual average atmospheric concentration to which they are exposed.

Source: Systems Applications, Incorporated, computations.

TABLE 5. TOP TWENTY MAJOR POINT SOURCES RANKED BY TOTAL DOSAGE* TO EXPOSED POPULATIONS FROM ALL STUDIED CHEMICALS EMITTED FROM EACH SOURCE

Ranking	Company	Location	Chemical	Individual Chemical Dosage [($\mu g/m^3$) persons]	Total Dosage [($\mu g/m^3$) persons]
1	FMC	South Charleston, WV	Carbon tetrachloride		2,310,000
2	ARCO	Houston, TX	Toluene	12,500	
			m-Xylene	9,870	
			o-Xylene	371,000	
			p-Xylene	302,000	
					695,370
3	Amoco	Decatur, AL	p-Xylene		558,000
4	Allied	Moundsville, WV	Carbon tetrachloride	725	
			Chloroform	18,900	
			o-Dichlorobenzene	382,000	
			Methylene chloride	70,600	
			Phosgene	6,190	
			Toluene	8,290	
					486,700

TABLE 5 (Continued)

Ranking	Company	Location	Chemical	Individual Chemical Dosage [(μg/m³) · persons]	Total Dosage [(μg/m³) · persons]
5	Amoco	Copper River, SC	p-Xylene		381,000
6	Monsanto	Sauget, IL	Benzyl chloride	1,580	
			Chlorobenzene	282,000	
			o-Dichlorobenzene	15,200	
			p-Dichlorobenzene	24,400	
			2,3,7,8-TCDD	1.6	
			Toluene	960	
					324,142
7	Vulcan	Wichita, KA	Carbon tetrachloride	36,400	
			Chloroform	44,700	
			2,3,7,8-TCDD	0.73	
			Methylene chloride	161,000	
					242,100

TABLE 5 (Continued)

Ranking	Company	Location	Chemical	Individual Chemical Dosage [(μg/m^3) · persons]	Total Dosage [(μg/m^3) · persons]
8	Dow	Freeport, TX	Allyl chloride	4,950	
			Carbon tetrachloride	1,780	
			Chloroform	3,830	
			o-Dichlorobenzene	67,400	
			Epichlorohydrin	19,100	
			Ethylene oxide	6,310	
			Methylene chloride	21,100	
			Phenol	8,320	
			Phosgene	1,110	
			Propylene oxide	22,700	
			Toluene	11,200	
			1,1,1-Trichloroethane	71,600	
			Trichloroethylene	1,550	
			m-Xylene	180	
			o-Xylene	100	
			p-Xylene	84	
					241,320
9	Du Pont	Parkersburg, WV	Formaldehyde		199,000

TABLE 5 (Continued)

Ranking	Company	Location	Chemical	Individual Chemical Dosage [(μg/m^3) · persons]	Total Dosage [(μg/m^3) · persons]
10	Union Carbide	South Charleston, WV	o-Dichlorobenzene	145,000	
			Phosgene	4,460	
			Propylene oxide	3,050	
			Toluene	5,560	
					158,070
11	Hercules	Hopewell, VA	Nitrobenzene		158,000
12	Shell	Dear Park, TX	Allyl chloride	2,610	
			Epichlorohydrin	40,300	
			Phenol	1,570	
			Toluene	7,520	
			m-Xylene	647	
			o-Xylene	45,200	
			p-Xylene	15,700	
					143,550
13	Du Pont	Deepwater, NJ	Carbon tetrachloride	25,000	
			Chlorobenzene	13,900	
			Chloroform	33,300	
			o-Dichlorobenzene	48,800	
			Nitrobenzene	330	
			Phosgene	3,500	
			Toluene	6,740	
					131,570

TABLE 5 (Continued)

Ranking	Company	Location	Chemical	Individual Chemical Dosage [$(\mu g/m^3) \cdot$ persons]	Total Dosage [$(\mu g/m^3) \cdot$ persons]
14	Mobay	Baytown, TX	o-Dichlorobenzene	116,000	
			Phosgene	2,080	
			Propylene oxide	123	
			Toluene	4,520	122,270
15	Dow	Plaquemine, LA	Carbon tetrachloride	14,900	
			Chloroform	8,440	
			Ethylene oxide	10,500	
			Methylene chloride	34,800	
			Nitrobenzene	13,200	
			Propylene oxide	4,430	
			1,1,1-Trichloroethane	30,300	116,570
16	Du Pont	Laplace, LA	Chloroprene	90,200	
			Toluene	25,400	115,600
17	Union Carbide	Institute, WV	Nitrobenzene	109,000	
			Propylene oxide	4,130	113,130

TABLE 5 (Concluded)

Ranking	Company	Location	Chemical	Individual Chemical Dosage $[(\mu g/m^3) \cdot \text{persons}]$	Total Dosage $[(\mu g/m^3) \cdot \text{persons}]$
18	Olin	Lake Charles, LA	o-Dichlorobenzene	104,000	
			Phosgene	1,320	
			Propylene oxide	57	
			Toluene	4,240	
					109,620
19	Celanese	Bishop, TX	Acetaldehyde	4,910	
			Formaldehyde	99,100	
					104,010
20	Perstorp	Toledo, OH	Acetaldehyde	12,100	
			Formaldehyde	75,700	
					87,800

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* Potential dosage: Exposed persons times annual average atomospheric concentration to which they are exposed.

Source: Systems Applications, Incorporated computations.

CAVEATS

The program goals can be technically met at different levels of rigor and detail. The rigor and detail possible in applying program results to health risk analyses depend not only on the quality of this program's results, but also on the validity of the health effects function used and its consistency with the results of this program and with practical constraints of an economic, social, or political nature.

The program team has sought to produce results that are as broad and flexible in scope and as rigorous and detailed as possible given constraints such as those identified below.

> Dispersed sources such as vehicle emissions and small industrial and commercial users have been linked to population, heating (degree-days) or other surrogates wherever possible. Thus, only coefficients of emissions per unit surrogate as a function of time (where appropriate) were developed for this source class.

> Site-specific exposure and dosage calculations were terminated at 20 kilometers. To avoid double counting of exposures at low concentrations, generic source exposure tabulations were terminated at distances corresponding to estimated typical source separations (dosages were not so terminated).

> Reactive production or decay rates of studied chemicals were developed only for prototype species. Reactive effects for each species were estimated using rates related to rates for the most appropriate reactive prototypical species. No attempt was made to model chemical reactions downwind of each source, and reactive effects were addressed by assuming constant rates.

- Diurnal shifts of population from residential to employment areas were not computed. Nationally comprehensive, disaggregated employment data are not available for this purpose. The methodology developed would, however, provide for this computation when specific site applications in future programs warrant assembly of a data base.
- Certain existing data that would support more detailed city specific fuel usage estimates were not collected because of resource limitations. For example, it is known that distillate fuel usage for space heating is not distributed solely by heating degree-day patterns; such use also depends on patterns of availability of alternative fuels or on the local cost of electricity, or both.
- Diurnal emissions patterns were not estimated. This is valid for continuously operated industrial sources, but it is not valid for most area or generic point sources or some specific point sources. For example, it is clear that some gas stations, dry cleaners, and businesses using degreasers close at night.
- Because diurnal emissions patterns were seldom estimated, correlations between meteorology and emissions parameters were not addressed. That is, night shutdowns were not correlated with slow, stable winds, nor with possibly preferred directions.
- The issue of the effect of world-wide exposures at vanishingly small concentrations was not addressed in the analysis (this issue is discussed, however, in Section 3).
- The issue of preferred spatial distributions of area or generic point sources was not resolved (e.g., four gas stations at a single intersection is a common deviation from a uniform density of stations).
- The atmospheric production of some species studied (e.g., formaldehyde) from other anthropogenic precursors (e.g.,

gasoline fumes) was not addressed. Such a study would require photochemical modeling of the entire country. The capability of modeling individual hydrocarbon species on such a scale is not now available.

> Natural sources of the selected species (e.g., the metals) were not considered.

> Computation of pollutant dispersion by building wakes does not address details of building shape.

RECOMMENDATIONS

We recommend that several features of the analysis and of the computer programs be addressed or improved in the course of their future use. Specifically, we recommend the following:

> Certain options (e.g., urban/rural choice of dispersion parameters) were suppressed in the final computer programs because implementing data were not available. We recommend some additional programming to permit more flexibility in the use of program options.

> An effort be made to determine and address space heating fuel use patterns.

> Available data on background concentrations of species of interest be reviewed for possible consideration in validating or supplementing dispersion studies, or both.

> Atmospheric production and associated ambient concentration estimates be made for species for which this is important.

> We recommend that detailed dispersion-exposure estimation modeling techniques be developed and applied for a small set of chemical-emitting specific sources. This would incorporate detailed plant emission characteristics, a complete decay/removal package, and population exposure characteristics.

> We recommend that a detailed urban areawide concentration-dosage modeling approach be developed. A typical metropolitan area may be selected as an example to determine the concentration-dosage patterns for certain chemicals of concern.

> We recommend that population distribution patterns and diurnal variations be examined for urbanized areas. This is of prime importance to the estimation of exposure--dosage of chemicals emitted from area sources.

> We recommend that the method of estimating the exposure-dosage be related to the current methods of estimating health effects of chemical exposure; that is, the implication of any choice of health effects model should be explicitly recognized in carrying out exposure/dosage estimations. This should provide basic information for focusing the modeling efforts on the critical threshold levels and time and dosage patterns of chemical exposure.

SECTION 2

DATA BASES

Four major types of data are essential for assessing exposures to and dosages of atmospheric chemicals:

- Emissions inventories of chemicals
- Atmospheric reactivities of chemicals
- Meteorological data
- Population distributions.

The acquisition, processing, and preparation of these data bases are delineated in this section.

EMISSIONS DATA

The development of emissions inventories for the 35 chemicals was conducted by Hydroscience, Incorporated (HI), under subcontract to SAI. HI has an extensive background in determining emission levels and controlling the release of pollutants from various manufacturing processes. HI is the prime contractor to the Emission Standards and Engineering Division (ESED), Office of Air Quality Planning and Standards, Environmental Protection Agency, for the project entitled Emissions Control Options for the Synthetic Organic Chemicals Manufacturing Industry, Contract No. 68-02-2577. The term of the contract is March 1977 to March 1980. The current estimated total cost is approximately $2.9 million. The primary objective is to gather sufficient information to allow ESED to fulfill its responsibility to establish new source performance standards and associated guideline documents for the synthetic organic chemical manufacturing industry. HI acquired the data necessary to identify emissions of chemicals that would provide a basis for dispersion model studies for human exposure assessment. Emissions were identified for each chemical for both production sites and user locations, and emissions characteristics such as quantity, rate, composition, and stack parameters were defined.

It was apparent that individual chemical emissions assessments could best be completed in a combined summary, especially in cases of common producer and user locations or where products are co-produced at the same location. Chemicals such as o-, m-, and p-cresols were summarized in one report. A total of 25 emissions summaries that cover the 35 chemicals were completed. All 25 summaries are included in Attachment A. The methodology used to identify chemical emissions is discussed here together with summarized emissions results and uncertainties involved in developing the emissions inventories.

Source Identification

In this study we identified three distinct categories of sources; each source category presents different data-gathering problems.

Specific Point Sources--

Specific point sources are defined as known locations identifiable by geographic coordinates for which the emissions of a specific chemical can be estimated and assigned. Specific point source locations were determined from a variety of published sources:

> 1978 Directory of Chemical Producers and Chemical Economics Handbook, published by Stanford Research Institute.

> "Chemical Marketing Reporter."

> U.S. Government publications, such as the U.S. Tariff Commission's "1977 Synthetic Organic Chemical Production and Sales."

> Reference guides, such as the "1977 Kline Guide to the Chemical Industry."

> Other sources, such as trade associations, trade journals and periodicals, and technical journals and periodicals.

Once the point source locations (including company name, city, and state) were determined, geographic coordinates were assigned. Most of the geographic coordinate information was obtained via personal communication with various state air agencies or, in some cases, from EPA regional offices. Information also was obtained from emissions inventory files; in some cases, HI determined coordinates by using United States Geological Survey maps. Some of the geographic coordinates obtained were in Universal Transverse Mercator units (UTMs), which were converted by use of a computer program to geodetic coordinates (latitude/longitude) by SAI.

After the locations were identified, the total quantity of the specific chemical produced or used at each of the sites was estimated. Total chemical production and use quantities were obtained from published sources. Three methods were used to determine individual site production and use quantities. When possible, total capacity and individual plant capacity figures were obtained. Total production and industry use was then distributed over each site based on the ratio of the site capacity to the total industry capacity. This was done because the total industry capacity is a much more accurate estimate than is the individual site capacity. In a second method, used in a few cases, average site capacities were estimated because only ranges of site capacities were known. In such cases, production and use quantities were then distributed by ratioing the average site capacity to the total industry capacity. Using the third method in cases for which individual site capacity figures were not available, the total quantity of production or use was distributed evenly over all sites in the industry or apportioned on the basis of number of employees at each site.

Prototype Point Sources--

Prototypes were defined and analyzed for some point sources because the sources are too numerous or unknown to allow identification of specific locations with geographic coordinates. Prototype model sources were defined for different regions and were modeled in the same fashion as specific point sources. The results were then scaled to represent all sources of the same nature. Examples of this type of source are power plants, refineries, and gas stations. Prototype point sources were used to analyze some specific chemical uses and most incidental sources of the chemicals assessed in this program.

To enable a regional analysis of exposure from sources analyzed by prototype, the prototype model source had to be defined and the number of sources in each of the geographic regions had to be determined. Total usage was then distributed over each of the regions by assuming an average quantity per site or by apportioning the use based on the number of employees in each region involved in the use of that specific chemical. Incidental source locations were distributed in the same manner.

Area Sources--

Area sources are those sources of chemical use or incidental emissions that could not be described as either a specific point source or as a generic point source because the use is too widespread or unknown. Such sources included home, business, and transportation uses of specific chemicals such as p-dichlorobenzene for moth control or toluene as a solvent in paints or as a constituent of gasoline.

Emission Estimations

Emissions Factors--

Emissions factors were developed to estimate the emissions from the production, consumption, and incidental formation of the various chemicals assessed. The emissions factor is expressed as the total pounds of a specific chemical lost to the atmosphere per pound of the chemical produced or used. Multiplication of the emissions factor by the quantity of the chemical produced or used at an individual site or in a specific geographic region during a specific time period yields the estimated chemical emissions, in pounds, for that location.

The total emissions resulting from the production or chemical intermediate use of a specific chemical are a summation of process, storage, and fugitive emissions losses:

- Process emissions are discrete losses that occur at process vents from reactors, columns, and other types of plant equipment.
- Storage emissions include losses from the raw material feed, in-process and final product storage tanks, as well as from loading and handling losses.
- Fugitive emissions are losses that result from plant equipment leaks, visual openings, evaporation from waste products, and other nondiscrete sources.

For most chemicals emitted from chemical production and intermediate consumption facilities, emissions factors were estimated spearately for process vent, storage emissions, and fugitive emissions. However, in some cases, only a total emissions factor could be determined, and further breakdown was not possible given the lack of emissions data at those specific sites.

Emission factors were not used to determine losses of chemicals used in solvent applications. Emissions resulting from solvent applications were estimated by assuming that all the solvent used, or all but a small waste fraction of the solvent used, is eventually released to the atmosphere. For the purpose of this report, emissions from the export of specific chemicals were assumed to be negligible. To develop specific chemical emissions factors, data from four different types of information sources were used:

> Level A--Plant Site Visits: These data were obtained by Hydroscience while performing tasks for EPA contract No. 68-02-2577, "Emission Control Options for the Synthetic Organic Chemical Manufacturing Industry." Under this contract HI assessed approximately for uncontrolled, controlled, and best estimates of current volatile organic compound (VOC) emissions resulting from chemical production facilities. Data were obtained by actual site visits to selected producers. Emissions estimates were developed for model plants based on the data obtained by visiting two or more producers of each chemical assessed. The emissions factors derived from this information reflect some degree of control and include only the estimated losses of the specific chemical in question. Other associated VOC losses were not included in the emissions summaries. This level of information was considered the best because it includes the most recent data available, and it incorporates some level of existing control in the emissions estimates.

> Level B - State Air Emission Inventory Questionnaires (EIQs): The air EIQs for most manufacturing sites are on file at various state air agencies throughout the United States. Hydroscience has obtained air files from Texas, Louisiana, Illinois, New Jersey, and others states, on

approximately 200 chemical and petrochemical manufacturing sites. These files were used to develop emissions factors for a number of the chemical-emitting processes. Emissions data on most of the questionnaires include total quantities per year of various kinds of VOC emissions from process and storage vents as well as fugitive estimates. The total emissions of a specific chemical were tabulated from process, storage, and fugitive sources for one or more producers and divided by the total production expressed as a percentage of a plant's rated capacity. The quality of the emissions data usually varies considerably. Process vent data are usually obtained from test results, while storage tank losses are usually based on AP-42 calculations. Fugitive estimates, if made, are normally obtained by the material balance method. As in the case of Level A data, only the emissions of the specific chemical in question were estimated. Other associated VOC emissions were not included in the emissions estimates.

> Level C--Other Published Sources: These emissions factors were obtained from a variety of published reports prepared by other contractors for the EPA. In the individual chemical summaries, the specific emissions factor obtained from these sources is referenced: In most cases, the accuracy of these data is not known, since the specific information used to derive the emissions factors is not given. This level of information was used only if Level A or B data were not available.

> Level D--Hydroscience Engineering Estimates: In some cases, emissions factors were not available from any of the three source levels previously discussed. Rather than omit these sources of emissions entirely, emissions estimates were made by HI process engineers. These estimates

were made using synergism between the unknown process and a process that had been previously defined. In other instances, an emissions factor for an unknown chemical intermediate use of a specific chemical was calculated based on a weighted average factor of all the other known chemical intermediate uses of the same chemical. Although specific quantification of the data quality is unknown, this is obviously the least accurate source of the four levels used.

Vent Parameter Data--

Vent parameter data are necessary for dispersion modeling of the chemical emssions. The vent parameter data in each of the chemical summaries include the number of process and storage tank vents, vent height, vent diameter, gas discharge temperature, gas emission velocity, fugitive discharge area, and building cross-sectional area. These data were obtained from the same four source levels discussed above, under emissions factors. Some data were supplied by producers during site visits, some data were obtained from EIQs, and some from other published reports or text books. The vent parameter data in the individual chemical summaries are usually an average of two or more sources of information. In cases where no data were available, they were estimated by Hydroscience engineers.

Summary and Conclusions

Emissions summaries covering 35 selected chemical compounds were completed for this program. The amount of effort required to complete each summary varied greatly. Chemicals that are produced and captively consumed, such as chloroprene, required minimal effort; chemicals with multiple production processes and multiple, complex uses and incidental sources, such as toluene, required considerably more.

The completed summaries and resulting emissions estimates are felt to be representative of current manufacturing activities for the production and use of each of the assessed chemicals. It is acknowledged that there are discrepancies between some of these estimates and others previously completed. The following points need to be considered when comparing these estimates:

- The base year for all chemicals assessed in this program is 1978. A number of the chemicals assigned for study have known toxicity problems, and considerable pressure has been exerted to restrict their use in numerous applications. As a result, almost half of the chemicals assessed had lower production totals in 1978 than in previous years. In addition, most solvent applications, which are usually the single largest source of emissions for most chemicals, have negative growth forecasts because increased concern for health and safety have brought about further use restrictions. Reduced production levels will result in reduced emissions, assuming the percent lost remains constant. Reduced solvent usage will markedly reduce total nationwide emissions of a chemical.
- The emissions factors used to estimate emissions represent only the fraction of the specific chemical that is lost. They do not take into account other associated volatile organic compounds (VOC) that normally are emitted along with the chemical being assessed. For example, nitrobenzene accounts for less than 20 percent of the total VOC emitted from nitrobenzene manufacture and captive use to produce aniline.
- Some degree of control is inherent in most of the data used to compute emissions factors. The factors do not represent completely uncontrolled emissions losses. As more old plants are taken out of service and replaced by

new ones with a greater number of more efficient control devices, the overall emissions factors will be reduced. This might result in smaller total industry emissions even if production were to increase significantly.

METEOROLOGICAL DATA

The dispersion computations carried out on this program require input data on wind speed, wind direction, and the intensity of atmospheric turbulence. The turbulence intensity was represented, as usual, by the atmospheric stability class.

Acquisition and Processing of STAR Data

Martin and Tikvart (1968) developed a computer program (the "STAR," or STability ARray program) that generated frequencies and percentage frequencies of wind direction by speed classes for each stability category from routinely collected data. The specifications of stability categories depending on wind speed and sky cover were set up by Pasquill (1961) and were modified by Turner (1964). The program was adopted for use at the National Climatic Center (NCC) in Asheville, North Carolina, where archived records of all national reporting weather stations are kept. The most up-to-date version of the STAR data from all STAR stations in the country was obtained on magnetic tape from NCC, and the matrices of STAR frequencies used in this study were taken from these tapes.

The STAR data obtained from NCC for this study were reprocessed for the following reasons:

> There are more than one set of frequency summaries for most STAR stations. By way of illustration, STAR station 14819 (Chicago/Midway) has 27 sets of data corresponding to different periods of record and different methods of

categorizing stability (e.g., one method distinguishes between day and night hours; another does not). It would be time-consuming to select the appropriate set of data for use each time a source is studied. Rather, selection should be conducted uniformly using the same criteria, and the most appropriate set of data would be used for each station.

> The entire STAR data consist of six files, and the stations are arranged in numerical order of their station codes within files 1 to 4, file 5 and file 6. Without reprocessing the data, the tape must be fully scanned for each source, the cost alone of which is sufficient incentive for data reprocessing.

> Not all data sets for all stations are in the same format or array. The great majority of data sets are developed for 16 wind directions, but there are a few with only 8. The greatest variation in the data format involves the specification of stability categories. The number of stability categories defined for different data sets varies from five to eight, and the most common variation was the inclusion/exclusion of day and night distinctions. The day-night splits were based on probabilities provided in the current STAR algorithm. The dispersion model is based on the availability of daytime and nighttime STAR data, so a day-night STAR data set was developed for each station.

The first stage in the development of an appropriate STAR data base was to manually select the most appropriate set of frequency summaries for each STAR station. The STAR Tabulations Master List (National Climatic Center, 1979) was used to make the selection by applying the following criteria, arranged here in order of importance:

- Data sets with errors or incomplete data were deleted.
- Data sets based on measurements conducted during a limited time period in a day or under special conditions would not be used.
- Data sets covering only parts of years would not be used.
- Data sets with day-night split would be selected in preference to those for which there is no day-night breakdown.
- Data sets with the longest recording period would be selected.
- Data sets with seven stability categories would be selected in preference to those with eight; sets having six and five categories would be selected last.
- Data sets with the most recent records would be selected preferentially.

The selected data sets were then reprocessed into a common format. A computer program was coded and used for selecting the appropriate data sets and converting these data sets with different specifications of stability categories into the default stability array with 16 wind directions, 6 wind speed classes and 7 stability categories (A, B, C, D_{day}, D_{night}, E, and F). Following are the basic rules used in conducting such conversions (U.S. EPA, 1977):

- Day-night data sets with seven stability categories are in the default format.
- For day-night data sets with six stability categories, a seventh category, F, would be added with all zeros for its frequencies (F frequencies having already been assigned to E).
- For day-night data sets with eight stability categories, the frequencies for the last two stability categories (F and G) would be combined into a single category (F).

> For data sets with five stability categories, the fourth category (D) would be split into two categories (D_{day} and D_{night}) with 60 percent of the frequencies assigned to D_{day} and 40 percent to D_{night}. The original fifth category would become category E, and a new category with all zero frequencies would be added as category F.

> For data sets with six stability categories, but without a D_{night} category, the fourth category would be split (60:40) into categories D_{day} and D_{night}.

> For data sets with seven stability categories, but without a D_{night} category, the fourth category would be split (60:40) into D_{day} and D_{night}, and the last two categories in the original data set would be combined to form category F in the new default format.

> For data sets with eight stability categories, but without a D_{night} category, the fourth category would be split (60:40) into D_{day} and D_{night}. The last three categories in the original data set would be combined to form category F in the new default format.

The reprocessed data sets would have a format including 16 wind directions, six wind speed classes, and seven stability categories with categories A, B, C, and D_{day} in the daytime and categories D_{night}, E, and F in the nighttime. There are data sets for 311 stations in this reprocessed STAR data file; their locations and recording periods are listed in Table 6*. This data file was used for dispersion modeling of chemical emissions from specific and generic point sources. It is also in a form suitable for direct application for most long-term air quality modeling.

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* Because of its length, this table appears at the end of this subsection on pp. 74 ff.

STAR Station Selection

Meteorological data recorded at the STAR station nearest to the source may be used in the dispersion modeling. However, local meteorological trends and topographic features may be more important factors in selecting a STAR station than is the absolute distance between the source and the station. A STAR station with climatological conditions most similar to those of the source of emissions may not be the nearest station, so the STAR stations were manually selected to take into account these factors.

The STAR station selection process developed and used in this study consists of a crude candidate identification process and a detailed assessment process.

Preliminary Candidate STAR Station Identification Process

The purpose of the preliminary process is to identify 2 to 10 candidate STAR stations for each major point source. The major criteria used in selecting these candidates are the availability of STAR data and the absolute distance between the source of emissions and the STAR station. Only those 311 stations listed in Table 6 were considered STAR stations here. The following steps were involved in this process:

> All of the 311 STAR stations were computer-plotted on four transparency maps [(Figures 3(a) to 6(a)].[*] The five-digit code of each STAR station was printed on the maps with the third digit representing the exact location of the station.[†]

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[*] Because of their length, these figures appear at the end of this subsection on pp. 90 ff.

[†] All codes that do not overlap in printing are presented in Figure 3(a). Potential overlapping codes are printed on subsequent figures [4(a) - 6(a)].

> Information on each specific point source of emissions was collected:
  - Company name.
  - Plant location.
  - Geodetic coordinates (longitude and latitude).

> Each of the sources was computer-plotted on a map with the same coordinates and scales. For example, the six sources as plotted on the background maps of Figures 3 through 6 represent six major chemical-emitting sources in the United States (see Table 7).

> By overlapping the STAR station transparency maps and the emissions source maps, the candidate STAR stations were identified for each emissions source based on the nearness of the STAR stations to the emissions sources.

TABLE 7. LOCATION OF SIX MAJOR CHEMICAL-EMITTING SOURCES*

No.	Company	Location	Latitude	Longitude
1	Dow	Freeport, TX	28°59'30"	95°23'35"
2	Amoco	Decatur, AL	34°36'12"	86°58'24"
3	Celanese	Bishop, TX	27°34'06"	97°49'27"
4	DuPont	Laplace, LA	30°04'00"	90°32'00"
5	Hercules	Hopewell, VA	37°15'34"	77°17'14"
6	FMC	S. Charleston, WV	38°22'10"	81°40'02"

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* From Table 3.

Detailed STAR Selection Process

Of paramount importance in this process is the matching of STAR stations and emissions sources that are in similar local meteorological regimes and are influenced by similar orographic (topography on the scale of mountain ranges) conditions. Major features considered here include the following:

> Surface thermal patterns, which can affect the local wind. For example, the local sea-land breeze wind system is usually limited to surface-based layers several hundred meters thick. This layer, of course, is where chemicals are emitted; it is important in our study, especially for chemical plants located on ocean coasts or adjacent to large lakes. Another example concerns fohn winds, the influence of which was considered for emissions sources located in Montana (Chinook) and in Los Angeles County (the Santa Ana wind). About 10 STAR stations were chosen in consideration of local winds.

> Wind patterns are taken from the Climatic Atlas (U.S. Environmental Data Service, 1968) and from maps of the U.S. Geological Survey (1:500,000; 1:125,000). We have matched about 20 emissions source-STAR station couples for Pacific and Atlantic coasts and Great Lakes shore.

> Topographical effects, such as that of mountain-valley wind. The behavior of the wind in ridge-valley topography depends, on one hand, on the relationships between the wind direction and the solar azimuth, and the orientation of the ridge lines and valleys on the other. These local wind effects were taken into consideration for selection processes, especially for emissions sources located in the valleys of the Cascades and coastal ranges (northwestern states) or the Appalachian Mountains (Eastern states).

> Urban effects, including wind flow disturbances by urban thermal or frictional elements such as organized patterns of urban skyscrapers (Chicago, New York City, Los Angeles metropolitan, etc.). Such features substantially influence airstream and, consequently, the diffusion of air contaminants. If an emissions source is located in a small city, and if STAR stations in a large city and in a small city are equidistant from the emissions source, then preference was given to the STAR station in the small city.

If two or more STAR stations were equally appropriate, preference was given to the station with the longest and most recent period of record; this information can be found in Table 6.[*]

Table 8[†] lists all the specific point sources identified in this study, together with the STAR station selected for each. The latter were selected by means of the selection process described above. Table 9 lists the location and the selected STAR stations for the 12 PCB incinerators.

Meteorological Data Base for Prototype Point Source Modeling

A prototype model source was defined to represent all the sources of the same nature in each region,[§] so it was desirable to define a set of meteorological data for dispersion modeling that is representative of the whole region. However, the use of a mean or composite matrix of climatological frequencies of occurrence in a regional model source emissions dispersion estimation would not be appropriate, because the averaging pro-

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[*] pp. 74 ff.

[†] pp. 82 ff.

[§] See Figure 1.

TABLE 9. SELECTED STAR STATIONS FOR PCB INCINERATORS

NO.	SITE	LATITUDE	LONGITUDE	STAR STATION
1	ATLANTA, GA	33 45 17	84 22 51	13874
2	BATON ROUGE, LA	30 33 35	91 15 30	13970
3	BRIDGEPORT, NJ	39 46 0	75 22 0	13739
4	CHICAGO, IL	41 52 0	87 43 38	14819
5	DEER PARK, TX	29 45 50	95 9 0	12906
6	DENVER, CO	39 43 12	105 0 0	23062
7	EL DORADO, AR	33 14 38	92 18 45	93992
8	LOS ANGELES, CA	34 0 0	118 0 0	23174
9	RICHMOND, VA	37 28 53	77 25 6	13740
10	SANDUSKY, OH	40 26 15	82 41 21	14891
11	SAN FRANCISCO, CA	38 0 0	122 0 0	23234
12	WATERFORD, NY	42 49 3	73 45 13	14735

cess leads to loss of characteristic biases in the original records. For example, if the prevailing wind is from a different direction at each of four stations that are averaged, the mean will have a more isotropic distribution with no strongly prevailing direction. Therefore, typical climatological data recorded at STAR stations that are representative of each region were selected and used for generic source modeling; the Climatic Atlas of the United States (1968) was used as the basis for selection. The major criteria used in selecting each representative STAR station include the following:

- Representativeness of annual surface wind rose*
- Availability of STAR data at the station
- Size of the urban area at or near station.

Table 10 lists the code and location of the STAR station selected for each region. The meteorological data recorded at these stations were used to estimate the concentration patterns in the vicinities in generic point sources.

POPULATION DISTRIBUTION DATA BASES

The estimation of human exposure to atmospheric chemicals requires knowledge of both concentration patterns and population distributions. Errors in specifying either of these factors affect the reliability of human exposure and dosage estimates. The acquisition, validation, and processing of population data were performed by Minimax Research Corporation under subcontract to SAI. This subsection summarizes the approaches and results of these efforts in these aspects. (The User's Manual and Programmer's Manual for applying the processed population data in specific point source exposure-dosage estimation are included in Attachment B.

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* Selected stations had wind roses like those of most other stations.

TABLE 10. SELECTED REGIONAL PROTOTYPE STAR STATIONS WITH REPRESENTATIVE REGIONAL CLIMATOLOGICAL CONDITIONS

Region Code	Region	STAR Station				
		Code	Site	Location	Longitude	Latitude
1	New England	14739	Boston	Boston/Logan	71°02'	42°22'
2	Middle Atlantic	94789	New York	New York/J.F. Kennedy	73°47'	40°39'
3	East North Central	14855	Chicago	Glenview	87°50'	42°05'
4	West North Central	14942	Omaha	Omaha	95°54'	41°18'
5	South Atlantic	13874	Atlanta	Atlanta	86°26'	33°39'
6	East South Central	13882	Chattanooga	Chattanooga/Lovell	85°12'	35°02'
7	West South Central	12923	Houston	Galveston/Scholes	96°52'	29°16'
8	Mountain	23062	Denver	Denver/Stapleton	104°52'	39°45'
9	Pacific Coast	23174	Los Angeles	Los Angeles	118°24'	33°56'

Population Data Acquisition

The Computer Science and Applied Mathematics Division of the Lawrence Berkeley Laboratory (LBL) has assembled an extensive collection of computerized data bases from federal government agencies and contractors. Several of these data bases that could be used in assembling a population distribution data base were reviewed.

The LBL data bases are organized according to the system used by the U.S. Bureau of the Census. Statistics are reported at various levels: state, county, Standard Metropolitan Statistical Area (SMSA), census tract (CT), enumeration district (ED), or block group (BG), and so on. The SMSAs are composed of one or more contiguous counties (or, in New England, cities and towns). Counties within SMSAs are subdivided into census tracts (covering an average of about 6,000 people), and the tracts are subdivided into block groups (covering an average of about 800 people). With some exceptions, areas outside of SMSAs are not tracted. Non-SMSA counties were divided into enumeration districts (ED) in the United States in 1970. An ED in the non-SMSA counties would be equivalent in terms of average population to a BG in the SMSA counties.

The population distribution data bases must contain, at a minimum, the following information for each designated area (county, tract, or block group):

- The Federal Information Processing System (FIPS) code of the area.
- The 1970 census population count.
- The geodetic coordinates (latitude/longitude) of the 1970 census population centroid.

Other information would be useful, but not necessary. Such information would include, for example, area (water, land, and total) and population density.

To the fullest possible extent, the resolution of the population distributions should be commensurate with dispersion pattern resolution. The effective radius of dispersion of emissions varies considerably with source characteristics and atmospheric conditions. Some emissions are highly concentrated at certain azimuths and radii, whereas others are more uniformly distributed. Detailed population distribution statistics are required to estimate exposure to concentrated emissions. Using comparatively large areas, such as counties, as the geographic unit of enumeration could seriously bias the results in such cases. These considerations dictate the use of the finest resolution possible in compiling the population statistics. Unfortunately, however, the cost of creating, maintaining, and using a population distribution data base increases rapidly with the degree of geographic detail. Within the context of this study, cost must be balanced with level of detail. Accordingly, the current availability of population data bases at LBL was first reviewed.

County Level Population Data Bases--

A data base entitled "Geographic Area Code Index (GACI)" contains the following items for each state and county in the United States:

> FIPS code
> Name
> Geodetic coordinates of the population centroid
> Population
> Land, water, and total areas
> Population density.

This data base can be used in its present condition with only minor reformatting.

Census Tract Level Population Data Bases--

At the tract level, FIPS codes and population counts are readily available from several data bases. The most convenient source for codes and populations seems to be the "Master Enumeration District List (MEDList)." Centroids must be computed from one of two sources:

> The raw digitized tract boundaries in the "US by SMSA Census Tract" map data base, which contains coordinates for 1.09 million boundary points for some 35,900 tracts. These data have been used many times and are quite clean.

> The centroids of the constituent ED/BGs in the "Master Enumeration District List--Extended" (MED-X) data base.

Processing the tract map files would require the development of a moderately complex program, portions of which could be adapted from existing LBL programs. To cover an entire county, further processing would be required to merge the resulting tract level data base with portions of the county level data.

ED/BG Level Population Data Base--

The "Master Enumeration District List--Extended (MED-X)" data base contains, for each block group and enumeration district, the following variables:

> Complete FIPS codes.

> Population count.

> Latitude and longitude of population centroid (areas are not available).

This data base contains approximately 350,000 records and 45 million characters. However, the data base had not been cleaned, and the known defects in MED-X included the following:

> Several hundred illegal alphabetic characters in numeric fields.
> An unknown number of erroneous centroid coordinates.
> The omission of half of the state of Louisiana and part of Vermont.

Despite these defects, MED-X contains all of the essential information required in a readily usable form. It is arranged so that populations and centroids can be easily and cheaply computed for areas larger than ED/BGs, such as tracts and counties. As a result, it provides more options in choosing the degree of resolution of the population distribution data base for different parts of the country. In addition, the MED-X base was determined to have the most accurate data for both population counts and distribution, and it offers the finest resolution.

The severity of problems with MED-X was estimated to be marginal after spot checking for illegal alphabetic characters and comparing county centroids and populations computed from MED-X with those listed in the county level base discussed above. The MED-X data base was selected for this study.

Population Data Validation

MRC undertook a thorough evaluation of both the internal consistency of MED-X and its consistency with independent external figures. At the start of the validation effort, two copies of MED-X existed at LBL; one was already in LBL-compatible format from Argonne National Laboratory (the ANL version), which was missing approximately half of Louisiana and 15 ED/BGs in Vermont; and another in IBM-compatible format from Oak Ridge National Laboratory (the ORNL version), which had never been used at LBL. The ORNL versions of Louisanna and Vermont were found to be complete and were used to replace the corresponding missing portions of the Argonne version. This revised version of MED-X was subjected to a detailed evaluation.

The MED-X validation process consisted of five separate tasks:

- Detection of missing or altered data resulting from tape errors.
- Verification of record formats (typographical errors and records out of order).
- Comparison of population sums of ED/BGs in each county to MED-X county population figures.
- Comparison of ED/BG centroid coordinates with digitized county boundaries.
- Comparison of MED-X state and county population figures with published 1970 census figures.

The first three tasks were conducted to check the internal consistency of the MED-X data base. The last two tasks were external checks performed to assess the overall accuracy of MED-X with respect to incorrect or geographically misplaced populations. Two kinds of errors cannot be detected by comparison with other independent sources, namely, misplaced ED/BGs that fall within the encompassing census areas and errors in individual ED/BG population figures.

Such errors, if reasonably infrequent, would have little effect on the final exposure results except in the rare instance that a substantial population error occurred in the immediate vicinity of an emissions source. The 20 km radius exposure area about each source covers only 0.0025 percent of the area of the contiguous U.S., and only over a small part of that area do the chemical concentrations vary widely. Therefore, such rare errors are extremely unlikely to significantly affect the exposure results.

The results of each of the five validation tasks may be summarized briefly.

Missing Records--

Besides the missing data for Louisiana and Vermont, which were replaced by the ORNL version, there was no detection of missing or altered data.

Format Consistency--

Four typographical errors were found and corrected. These errors took the form of nondigits in numeric fields. Incorrect digits undoubtedly exist, but they cannot be detected except by their effects on the population distribution. The order of records on the tape was found to be correct.

Internal Population Consistency--

Populations for 2 of the 3141 counties (Keokuk County, Iowa, and Bergen County, New Jersey) did not equal the total population of their ED/BGs. The cause of these errors has not been determined, and no correction has been made. The total of the ED/BG populations for Keokuk County fell short by 173; the total for Bergen County was 3,387 over the corresponding county figure.

ED/BG Coordinate Consistency--

A total of 12,859 (5.5 percent) of the ED/BGs in the contiguous United States, containing 5.75 percent of the population, fell outside the digitized boundaries of their corresponding counties. Table 11 classifies these ED/BGs by the distance of their centroids from the nearest point on the county boundary. Undoubtedly, other ED/BGs with incorrect coordinates fall within their boundaries; therefore, the error counts above are lower bounds. However, most of the ED/BGs that fall immediately outside (within 1 km) are attributable to either digitizing errors in the county boundaries or concavities in the ED/BG boundaries that cause the ED/BG centroid to be outside its boundary; such discrepancies are not errors. Further-

TABLE 11. DISTRIBUTION OF ENUMERATION DISTRICTS/BLOCK GROUPS (ED/BDs) HAVING POPULATION CENTROIDS LOCATED OUTSIDE THEIR CORRESPONDING COUNTIES

Distance from County Line (km)	No. of ED/BGs	Proportion of Outlying ED/BGs	Proportion of All ED/BGs
0.1	2,182	16.97%	95.37%
0.5	7,533	58.58	97.69
1.0	10,265	79.82	98.87
2.0	11,893	92.49	99.58
5.0	12,475	97.01	99.83
10.0	12,711	98.85	99.94
20.0	12,815	99.66	99.98
100.0	12,857	99.98	99.99
200.0	12,859	100.00	100.00

Source: Minimax Research Corporation consistency check of U.S Census Bureau files.

more, the county codes used in the comparison were those to which the ED/BGs belonged in 1970. Since that time, some of the county boundaries have moved and the county boundary file has been updated. Thus, some of the ED/BGs that fell more than 2 km outside their county boundaries may really be outside the current county boundaries. It is interesting that of the 922 ED/BGs that fell between 2 and 20 km outside their counties, 564 occurred in only 23 of the 188 associated counties. This concentration of discrepancies in so few counties suggests the affect of boundary changes rather than of coordinate errors.

Statistical analysis of the outliers that are almost certainly errors (those beyond, say, 5 km) may provide an estimate of the distribution of all such errors. Alternately, ED/BG coordinates could be compared to digitized census tract boundaries for SMSA counties. These additional tasks could further quantify the probable error by county, but they seem unnecessary.

County Population Consistency--

The county population figures from the MED-X county records were compared to the 1970 county populations in Table 24 of the 1970 Census of Population, United States Summary, Vol. 1, Part 1, keypunched at LBL. The discrepancies were then double-checked manually against the published document. Of the 3141 counties and county equivalents compared, 46 (1.5 percent) did not match. The net population difference for the entire country was 34,907 (0.017 percent of the 1970 U.S. population). It is very likely that the published figures, which were the first ones produced by the Bureau of the Census, are less reliable than those in MED-X.

MED-X was found to be the most accurate and the most detailed of all the population distribution data bases at LBL. The relatively few errors found in MED-X affect exposure results less than the lower resolutions of the alternatives.

Population Data Processing

MED-X contains the population centroid coordinates (latitude and longitude) and the 1970 population of each ED/BG in the country (50 states plus the District of Columbia). In addition to these essential data, MED-X contains large amounts of descriptive and summary data. While these data were invaluable in verifying the high degree of accuracy of MED-X, they interfere with efficient access to the small subset of information needed for the exposure calculations. Moreover, MED-X is collated by Federal Information Processing System (FIPS) codes, which are assigned alphabetically by state and county. These codes are not appropriate for accessing ED/BG records by their locations. The efficiency design goal required that a data base be created containing only the essential information, and that it be organized to permit access to only the relevant geographic areas. To this end, a new, smaller data base was produced from MED-X.

MED-X was reduced in two phases to a randomly-accessible binary file that contains only the data essential for exposure estimation. An indexing system was also created to locate the appropriate ED/BGs. A separate binary file of county-level growth factors, based on the 1970 to 1978 growth factor at the county level and used for scaling population figures to 1978 estimations, was also produced. The entire system, based on MED-X ED/BG population data, was used for estimating the human exposure and dosage of atmospheric chemicals resulting from specific point source emissions.

ATMOSPHERIC TRANSFORMATIONS OF TOXIC COMPOUNDS

Species monographs for the 35 toxic compounds included in this study are presented in Attachment A. It is the purpose of this section to explain the procedures used to describe the transformations in the atmosphere that are undergone by the various compounds. However, the information presented is subject the following caveats:

> First, the gas phase photochemistry of many of these compounds is not well known; in several instances, no information about the behavior of the compound in the gas phase is available. Accordingly, many of the reaction rates given are estimates, with possibly large margins of error, based on liquid phase chemistry or on the known behavior of chemically related compounds.

> Second, a compound does not necessarily become less toxic even though it undergoes transformation and decay. A good illustration of the point is acetaldehyde, which decays to form formaldehyde--another compound on the list of toxic chemicals. It may be that some of the 35 toxic compounds decay to other substances perhaps even more toxic than the precursors; current lack of knowledge regarding formation yield and toxic effects could result in such occurrences passing unnoticed.

Given the considerable body of knowledge that does exist, the procedures discussed below were used to estimate the atmospheric lifetimes of the 35 toxic compounds.

Decay

A variety of studies have reported the lifetime or atmospheric residence time of many of the listed chemicals. Too often the basis for the decay estimates is not given, so in many cases we were unable to verify prior estimates of chemical reaction rates and could not compare and reconcile the results of these past studies. In recognition of the uncertainty of reaction data, we have adopted the concept of a reference species against which to compare the relative rates of reaction for the important photochemical pathways. We also state the assumed ambient concentrations of hydroxyl radical and ozone, the principal species that attack and degrade gas phase organic compounds.

Most chemical destruction of gaseous compounds in the atmosphere occurs by one of the following three mechanisms:

- Photolysis
- Reaction with free radicals (chiefly hydroxyl)
- Reaction with atmospheric oxidants (chiefly ozone).

The processes of photolysis and reaction with hydroxyl radicals occur only in the daytime. Hydroxyl radicals have a short atmospheric lifetime and require a continuing photolytic source to maintain their concentration.

Reference species for atmospheric reactivity selected for this study are as follows:

- Butane
- Propylene
- Formaldehyde.

Butane is used when a species is OH• reactive; propylene is used when a species is reactive to O_3; formaldehyde is the reference species for photolysis. Propylene is approximately seven times as reactive to OH• as butane (EPA, 1977).

The concentration of OH• assumed for the daylight hours is 5×10^6 molecule cm^{-3}, or 2×10^{-7} ppm (Wang et al., 1975). Ozone background is assumed to be 0.04 ppm. The decay rate for butane due to OH• reactions is 8.4×10^{-4} min^{-1}. The propylene decay rate due to oxidation by O_3 is 6×10^{-4} min^{-1}.

The photolytic decay rate of formaldehyde, averaged over the daylight hours at conditions near the equinox, is about 10^{-3} min^{-1}. The midday decay rate is about twice this figure. At the summer solstice, the daily decay rate is larger owing to increased duration of the day, but the maximum photolytic decay rate for the summer is still only about 2×10^{-3} min^{-1}; at solar zenith angles below 20°, photolysis rates become nearly constant (Killus et al., 1977).

Decay Rates for Classes of Compounds

The 35 compounds assessed in this study may be divided into six general categories (Table 12) on the basis of their general structure and the data available for each compound. The six categories are as follows:

> Solid substances for which no gas phase chemistry applies; all of these substances are metals except for TCDD (Dioxin).
> Well characterized compounds, i.e., substances for which some laboratory data exist as a basis for our estimates.
> Methane analogues, which are compounds with electronic configurations similar to methane and which are, therefore, quite unreactive.
> Aromatic compounds, with reactivities assumed to be similar to benzene or toluene.
> Formation products, which are compounds formed by atmospheric reaction.
> Miscellaneous.

The last two categories need further explanation. In the "Miscellaneous" grouping, four of the compounds--allyl chloride, chloroprene, hexachloropentadiene, and phosgene--are chlorine substituted compounds of hydrocarbons with high reactivity. Although chlorine substitution is expected to modify reactivity somewhat (Gay et al., 1976), we may say with some confidence that the reactivity of these compounds is also high. The reactivity of these four compounds is, to that extent, better characterized than for the other miscellaneous compounds. Estimates of the reactivity of the remaining four compounds may be in error to a substantial degree.

For the "formation products" category, the two nitroso-compounds may be formed from the nighttime reaction of nitrous acid (HONO) and precursor amines that have been inventoried. We have estimated the possible produc-

TABLE 12. DECAY RATE ESTIMATION CATEGORIES FOR 35 COMPOUNDS

Category					
Solids[*]	Well Characterized Compounds	Methane Analogues	Aromatics[†]	Formation Products	Miscellaneous
Beryllium	Acetaldehyde	Carbon tetrachloride	Benzyl chloride	Nitrosomorpholine	Allyl chloride
Dioxin[§]	Acrolein	Chloroform	Chlorobenzene	Dimethylnitrosamine	Chloroprene
Manganese	Cresols	Methylene chloride	Dichlorobenzenes	(Acetaldehyde)	Epichlorohydrin
Nickel	Formaldehyde	1,1,1, Trichloroethane	Nitrobenzene	(Cresols)	Ethylene oxide
	Toluene		Phenol	(Formaldehyde)	Hexachlorocyclopentadiene
	Trichloroethylene			(Phosgene)	PCBs
	Xylenes			(Ethylene oxide)	Phosgene
				(Propylene oxide)	Propylene oxide

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[*] No gas phase reactions.

[†] Benzene analogues.

[§] 2,3,7,8-TCDD

Source: Systems Applications, Incorporated, review of species characteristics.

tion rate for these nitroso-compounds. Photolysis of HONO and nitroso--compounds precludes the occurrence of significant concentrations of these compounds during the day.

Nitrous acid and dimethylamine react to yield dimethylnitrosamine and water (Lucas, 1933):

$$(CH_3)_2NH + HONO \rightarrow (CH_3)_2NNO + H_2O \quad .$$

Knowledge of the HNO_2 concentration, the dimethylamine concentration, and the rate of disappearence of dimethylamine, combined with the assumption of the bimolecular reaction expressed above; allows a rate constant to be calculated for the expression:

$$-\frac{d(CH_3)_2NH}{dt} = K \cdot P_{(CH_3)_2NH} \cdot P_{HONO} \quad .$$

The value was estimated to be $K = 0.08\ ppm^{-1}\ min^{-1}$ (Hanst et al., 1977). Assuming a homogeneous reaction, with a 100 percent yield of dimethylnitrosamine, the formation rate under normal atmospheric conditions can be estimated.

Nitrous oxide and nitrogen dioxide are two other pollutants of concern here. These two species, in the presence of water vapor cause the gas-phase formation of nitrous acid:

$$NO + NO_2 + H_2O \rightarrow 2HNO_2 \quad .$$

The equilibrium constant at 23°C has been estimated by Calvert et al. (1975) to be:

$$Keq = \frac{P_{HNO_2}^{\;\;2}}{P_{NO} \cdot P_{NO_2} \cdot P_{H_2O}} = 1.5 \times 10^{-6}\ ppm^{-1} \quad .$$

By assuming a moderatedly polluted urban air mix with a 1:1 mixture of NO and NO_2 of 0.05 ppm total and water vapor of 13,000 ppm, Hanst et al. (1977) have estimated the typical nighttime nitrous acid concentration to be 0.0035 ppm. This value was used here, together with the bimolecular formation expression in estimating the pseudo-first order reaction rate constant. It was estiamted to be:

$$\frac{d(CH_3)_2NNO}{dt} = K \cdot P_{HONO} \cdot P_{(CH_3)_2NH} \quad .$$

$$= (0.00028\ min^{-1})\ P_{(CH_3)_2NH} \quad .$$

This rate constant applies only in the nighttime. In sunlight, both the nitrous acid and dimethylnitrosamine would be destroyed by photolysis much faster they can be formed.

Because of the chemical similarity of dimehtylamine and morpholine, the same approach used for eatimating the ambient concentration of nitrosomorpholine. It should be noted that because of the cyclic structure of morpholine, the lone pair of electrons of the nitrogen atom are more susceptible to electrophilic attack, and therefore, the formation of nitrosomorpholine from reaction between morpoline and nitrous acid should proceed faster than the formation N,N-dimethylnitrosamine from reaction between dimethylamine and nitrous acid. However, there is no adequate data available to estimate the pseudo-first order formation rate constant for nitrosomorpholine, the estimate for dimethylnitrosamine was taken to be the same as for nitrosomorpholine.

A summary of estimated relative reactivity for each studied chemical is presented in Table 13. Also included in this table are the day and nighttime net effective decay rates based on the relative reactivities.

To treat the formation reactions of the remaining compounds in the formation products category is beyond the scope of this work. Relatively sophisticated photochemical models would be required for such an undertaking, and a full accounting of compounds not inventoried in this project would be required. For acetaldehyde, formaldehyde, and phosgene, in particular, this omission is unfortunate. Formaldehyde, for example, is emitted as roughly 1 to 2 percent of automobile exhaust, whereas the photochemical equilibrium for the compound is roughly twice this amount. Consequently, on a day of high photochemical reactivity, more than half the population exposure to formaldehyde may come from secondary formation. Similar inferences apply to acetaldehyde and phosgene. Phosgene is one of the major termination products of the decay of chlorinated hydrocarbons.

TABLE 13. PHOTOCHEMICAL REACTIVITIES OF SELECTED CHEMICALS

Chemical Species	Reactivity Toward			Reaction Rate Constant	
	OH· (%Butane)	O_3 (%Propylene)	Photolysis (%Formaldehyde)	Daytime	Nighttime
Acetaldehyde	4	0	0.5	4.36×10^{-3}	0
Acrolein	0.5	0.5	5	9.5×10^{-3}	3×10^{-4}
Allyl chloride	2	0.15	0	1.77×10^{-3}	9×10^{-5}
Benzyl chloride	2	0	0	1.68×10^{-3}	0
Beryllium	0	0	0	0	0
Bis-chloromethyl ether (BCME)	1	0	0	8.4×10^{-4}	0
Carbon tetrachloride	0	0	0	0	0
Chlorobenzene	0.33	0	0	2.8×10^{-4}	0
Chloroform	0	0	0	0	0
Chloromethyl methyl ether (CMME)	1	0	0	8.4×10^{-4}	0
Chloroprene	4.0	2	0	4.56×10^{-3}	1.2×10^{-3}
m-Cresol	12	0.1	0	1.01×10^{-2}	6×10^{-5}
p-Cresol	10	0.1	0	8.46×10^{-3}	6×10^{-5}
o-Cresol	10	0.1	0	8.46×10^{-3}	6×10^{-5}
o-Dichlorobenzene	0.5	0.05	0	4.5×10^{-4}	3×10^{-5}
p-Dichlorobenzene	0.5	0.05	0	4.5×10^{-4}	3×10^{-5}
Dimethylnitrosamine	--*	--	--	--	--
Dioxin (2,3,7,8-TCDD)	--	--	--	--	--
Epichlorohydrin	--	--	--	--	--
Ethylene oxide	1	0	0	8.4×10^{-4}	0
Formaldehyde	3	0	1	2.52×10^{-3}	0
Hexachlorocyclopentadiene	--	--	--	--	--
Manganese	0	0	0	0	0
Methylchloroform	0	0	0	0	0
Methylene chloride	0	0	0	0	0
Methyl iodide	0	0	0.05	5×10^{-5}	0
Nitrosomorpholine	--	--	--	--	--
Nickel	0	0	0	0	0
Nitrobenzene	0.5	0	0	4.2×10^{-4}	0
2-Nitropropane	--	--	--	--	--
PCB	0.05	0	0	4.2×10^{-3}	--
Phenol	2	0.15	0	1.77×10^{-3}	9×10^{-5}
Phosgene	--	--	--	--	--
Propylene oxide	--	--	--	--	--
Toluene	2	0	0	1.68×10^{-3}	0
Trichloroethylene	2	0	0	1.68×10^{-3}	0
m-Xylene	8	0	0	6.72×10^{-3}	0
p-Xylene	4	0	0	3.36×10^{-3}	0
o-Xylene	8	0	0	6.72×10^{-3}	0

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* reactivity unknown

TABLE 6. LOCATION AND RECORDING PERIOD OF STAR DISPERSION DATA FILES AS REPROCESSED FOR USE IN HUMAN EXPOSURE DISPERSION STUDIES

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
1	3133	YUCCA FLATS	NV	36 57	116 3	61/12	64/11
2	3813	MACON	GA	32 42	83 39	67/ 1	71/12
3	3816	PADUCAH	KY	37 4	88 46	60/ 1	64/12
4	3820	AUGUSTA	GA	33 22	81 58	70/ 1	74/12
5	3822	SAVANNAH	GA	32 8	81 12	69/ 1	73/12
6	3855	PENSACOLA	FL	30 21	87 19	67/ 1	71/12
7	3872	BECKLEY	WV	37 47	81 7	71/ 1	75/12
8	3927	FT WORTH	TX	32 54	97 2	71/ 1	75/12
9	3937	LAKE CHARLES	LA	30 7	93 13	70/ 1	74/12
10	4739	BELMAR	NJ	40 11	74 4	55/ 1	59/12
11	4743	PORTSMOUTH	NH	43 5	70 49	69/ 1	69/12
12	4751	BRADFORD	PA	41 48	78 38	70/ 1	74/12
13	12810	TAMPA	FL	27 51	82 31	65/ 1	69/12
14	12834	DAYTONA	FL	29 11	81 3	67/ 1	71/12
15	12835	FT MYERS	FL	26 35	81 52	69/ 1	73/12
16	12839	MIAMI	FL	25 48	80 16	70/ 1	74/12
17	12841	ORLANDO	FL	28 27	81 18	60/ 1	64/12
18	12842	TAMPA	FL	27 58	82 32	69/ 1	73/12
19	12844	WEST PALM B.	FL	26 41	80 6	70/ 1	70/12
20	12906	HOUSTON	TX	29 37	95 10	66/ 1	70/12
21	12917	PRT ARTHUR	TX	29 57	94 1	64/ 1	64/12
22	12918	HOUSTON	TX	29 39	95 17	64/ 1	68/12
23	12923	GALVESTON	TX	29 16	94 52	56/ 1	60/12
24	12925	BEEVILLE	TX	28 23	97 40	66/ 1	70/12
25	12947	COTULLA	TX	28 27	99 13	50/ 1	54/12
26	12958	NEW ORLEANS	LA	29 49	90 1	70/ 1	74/12
27	12960	HOUSTON, 12918	TX	29 59	95 22	71/ 1	75/12
28	13701	ABERDEEN	MD	39 28	76 10	55/ 1	57/12
29	13705	WASHINGTON	DC	38 49	76 52	66/ 1	70/12
30	13707	DOVER	DE	39 8	75 28	66/ 1	70/12
31	13713	GOLDSBORO	NC	35 20	77 58	66/ 1	70/12
32	13714	FT BRAGG	NC	35 10	79 1	66/ 1	70/12
33	13717	MYRTLE BEACH	SC	33 41	78 56	66/ 1	70/12
34	13721	PATUXENT RIVER	MD	38 17	76 25	62/ 1	71/12
35	13723	GREENSBORO	NC	36 5	79 57	68/ 1	72/12
36	13728	DANVILLE	VA	36 34	79 20	50/ 1	54/12
37	13732	GORDONSVILLE	VA	38 4	78 10	56/ 1	60/12
38	13733	LYNCHBURG	VA	37 20	79 12	69/ 1	73/12
39	13734	MARTINSBURG	WV	39 24	77 59	60/ 1	64/12
40	13735	MILLVILLE	NJ	39 22	75 4	50/ 1	54/12

TABLE 6 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
41	13736	MORGANTOWN	WV	39 39	79 55	50/ 1	54/12
42	13737	NORFOLK REG	VA	36 54	76 12	55/ 1	64/12
43	13739	PHILADELPHIA	PA	39 53	75 15	67/ 1	71/12
44	13740	RICHMOND	VA	37 30	77 20	74/ 1	75/12
45	13741	ROANOKE	VA	37 19	79 58	68/ 1	72/12
46	13743	WASHINGTON DC	DC	38 51	77 2	74/ 1	74/12
47	13744	FLORENCE	SC	34 11	79 43	60/ 1	64/12
48	13749	FREDERICK	MD	39 26	77 27	49/ 1	52/12
49	13753	ATLANTIC CITY	NJ	39 27	74 35	54/ 1	58/12
50	13773	QUANTICO	VA	38 30	77 19	65/ 1	69/12
51	13802	BELLEVILLE	IL	38 33	89 51	61/ 1	70/12
52	13806	FT CAMPBELL	KY	36 40	87 29	65/ 1	69/12
53	13807	FT KNOX	KY	37 54	85 58	64/ 1	68/12
54	13815	ALBANY	GA	31 35	84 7	69/ 1	73/12
55	13820	BILOXI	MS	30 25	88 55	60/ 1	64/12
56	13824	SAVANNAH	GA	32 1	81 8	66/ 1	70/12
57	13825	COLUMBUS	MS	33 39	88 27	66/ 1	70/12
58	13840	DAYTON	OH	39 49	84 3	64/ 1	64/12
59	13850	SELMA	AL	32 20	86 59	54/ 1	58/12
60	13865	MERIDIAN	MS	32 20	88 45	66/ 1	70/12
61	13866	CHARLESTON	WV	38 22	81 36	68/ 1	73/12
62	13868	PULASKI	VA	37 8	80 41	50/ 1	54/12
63	13870	ALMA	GA	31 22	82 31	54/ 1	58/12
64	13871	ANNISTON	AL	33 35	85 51	49/ 1	54/12
65	13873	ATHENS	GA	33 57	83 19	69/ 1	73/12
66	13874	ATLANTA	GA	33 39	84 26	69/ 1	73/12
67	13877	BRISTOL	TN	36 29	82 24	60/ 1	64/12
68	13881	CHARLOTTE	NC	35 13	80 56	69/ 1	73/12
69	13882	CHATTANOOGA	TN	35 2	85 12	68/ 1	73/12
70	13889	JACKSONVILLE	FL	30 30	81 42	70/ 1	74/12
71	13891	KNOXVILLE	TN	35 49	83 59	68/ 1	73/12
72	13895	MONTGOMERY	AL	32 18	86 24	60/ 1	64/12
73	13897	NASHVILLE	TN	36 7	86 41	71/ 1	75/12
74	13921	FT LEAVENWORTH	KS	39 22	94 55	62/ 1	70/12
75	13935	ALEXANDRIA	LA	31 23	92 18	70/ 1	74/12
76	13939	GREENVILLE	MS	33 29	90 59	56/ 1	60/12
77	13941	LAKE CHARLES	LA	30 13	93 10	58/ 1	62/12
78	13942	MONROE	LA	32 31	92 3	54/ 1	58/12
79	13945	FT SILL	OK	34 39	98 24	66/ 1	70/12
80	13956	JACKSON	MS	32 20	90 13	60/ 1	64/12

TABLE 6 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
81	13957	SHREVEPORT	LA	32 28	93 49	70/ 1	74/12
82	13958	AUSTIN	TX	30 18	97 42	69/ 1	73/12
83	13960	DALLAS	TX	32 51	96 51	69/ 1	73/12
84	13961	FT WORTH	TX	32 49	97 21	49/ 1	52/12
85	13962	ABILENE	TX	32 26	99 41	67/ 1	71/12
86	13963	LITTLE ROCK	AR	34 44	92 14	66/ 1	70/12
87	13964	FT SMITH	AR	35 20	94 22	55/ 1	74/12
88	13967	OKALAHOMA CITY	OK	35 24	97 36	70/ 1	74/12
89	13968	TULSA	OK	36 12	95 54	55/ 1	74/12
90	13969	PONCA CITY	OK	36 44	97 6	49/ 1	54/12
91	13970	BATON ROUGE	LA	30 32	91 9	70/ 1	74/12
92	13972	TYLER	TX	32 22	95 24	50/ 1	54/12
93	13976	LAFAYETTE	LA	30 12	91 59	54/ 1	58/12
94	13977	TEXARKANA	AR	33 27	94 0	63/ 1	67/12
95	13983	COLUMBIA	MO	38 58	92 22	64/ 1	68/12
96	13983	KANSAS CITY	MO	39 7	94 36	64/ 1	64/12
97	13994	ST LOUIS	MO	38 45	90 23	70/ 1	74/12
98	13995	SPRINGFIELD	MO	37 14	93 23	66/ 1	70/12
99	13996	TOPEKA	KS	39 4	95 38	63/ 1	72/12
100	14607	CARIBOU	ME	46 52	68 1	53/ 1	62/12
101	14611	BRUNSWICK	ME	43 53	69 59	60/ 1	69/12
102	14622	OLD TOWN	ME	44 57	68 40	60/ 1	64/12
103	14702	BEDFORD	MA	42 28	71 17	63/ 1	67/12
104	14704	FALMOUTH	MA	41 39	70 31	60/ 1	64/12
105	14706	WRIGHTSTON	NJ	40 1	74 36	66/ 1	70/12
106	14708	HEMPSTEAD	NY	40 44	73 36	59/ 1	60/12
107	14712	READING	PA	40 23	75 58	49/ 1	49/12
108	14717	ROME	NY	43 14	75 24	66/ 1	70/12
109	14735	ALBANY	NY	42 45	73 48	60/ 1	64/12
110	14736	ALTOONA	PA	40 18	78 19	49/10	54/ 9
111	14737	ALLENTOWN	PA	40 39	75 26	64/ 1	73/12
112	14739	BOSTON	MA	42 22	71 2	66/ 1	70/12
113	14740	HARTFORD	CT	41 56	72 41	55/ 1	64/12
114	14742	BURLINGTON	VT	44 28	73 9	70/ 1	74/12
115	14745	CONCORD	NH	43 12	71 30	60/ 1	64/12
116	14747	DUNKIRK	NY	42 30	79 17	49/ 1	53/12
117	14748	ELMIRA	NY	42 10	76 54	50/ 1	54/12
118	14750	GLENS FALL	NY	43 21	73 37	50/ 1	54/12
119	14751	HARRISBURG	PA	40 13	76 51	64/ 1	73/12
120	14752	HARTFORD	CT	41 44	72 39	48/ 1	52/12

TABLE 6 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
121	14757	POUGHKEEPSIE	NY	41 38	73 53	50/ 1	54/12
122	14761	PHILIPSBURG	PA	40 53	78 5	50/ 1	54/12
123	14762	PITTSBURGH	PA	40 21	79 56	74/ 1	75/12
124	14763	PITTSFIELD	MA	42 26	73 18	48/ 1	53/12
125	14764	PORTLAND	ME	43 39	70 19	60/ 1	64/12
126	14765	PROVIDENCE	RI	41 44	71 26	64/ 1	73/12
127	14771	SYRACUSE	NY	43 7	76 7	55/ 1	64/12
128	14777	WILKES-BARRE	PA	41 20	75 44	64/ 1	73/12
129	14778	WILLIAMSPORT	PA	41 15	76 55	64/ 1	73/12
130	14790	SOUTH WEYMOUTH	MA	42 9	70 56	70/ 1	74/12
131	14793	WILLOW GROVE	PA	40 12	75 8	68/ 1	71/12
132	14806	RANTOUL	IL	40 18	88 9	58/ 1	62/12
133	14820	CLEFELAND	OH	41 24	81 51	70/ 1	74/12
134	14821	COLUMBUS	OH	40 0	82 53	70/ 1	74/12
135	14822	DETROIT CITY	MI	42 25	83 1	70/ 1	74/12
136	14825	FINDLAY	OH	41 1	83 40	50/ 1	54/12
137	14837	MADISON	WI	43 8	89 20	70/ 1	74/12
138	14839	MILWAUKEE	WI	42 57	87 54	70/ 1	74/12
139	14840	MUSKEGON	MI	43 10	86 14	74/ 1	74/12
140	14842	PEORIA	IL	40 40	89 41	70/ 1	74/12
141	14843	PERRY	OH	41 47	81 7	49/ 1	49/12
142	14845	SAGINAW	MI	43 26	83 52	49/ 1	54/12
143	14855	GLENVIEW	IL	42 5	87 50	74/ 1	74/12
144	14860	ERIE	PA	42 5	80 11	64/ 1	73/12
145	14891	MANSFIELD	OH	40 49	82 31	70/ 1	74/12
146	14895	AKRON	OH	40 55	81 26	64/ 1	73/12
147	14898	GREEN BAY	WI	44 29	88 8	69/ 1	73/12
148	14904	LINCOLN	NB	40 51	96 46	59/ 1	63/12
149	14913	DULUTH	MN	46 50	92 11	70/ 1	74/12
150	14914	FARGO	ND	46 54	96 48	70/ 1	74/12
151	14918	INT FALLS	MN	48 34	93 23	70/ 1	74/12
152	14920	LA CROSSE	WI	43 52	91 15	49/ 1	53/12
153	14922	MINNEAPOLIS	MN	44 53	93 13	65/ 1	74/12
154	14923	MOLIN	IL	41 27	90 31	70/ 1	74/12
155	14925	ROCHESTER	MN	43 55	92 30	69/ 1	73/12
156	14926	ST CLOUD	MN	45 35	94 11	67/ 1	71/12
157	14931	BURLINGTON	IA	40 47	91 7	67/ 1	71/12
158	14933	DES MOINES	IA	41 32	93 39	72/ 1	72/12
159	14935	GRAND IS	NB	40 58	98 19	64/ 1	64/12
160	14938	KIRKSVILLE	MO	40 6	92 33	50/ 1	54/12

TABLE 6 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
161	14940	MASON CITY	IA	43 9	93 20	70/ 1	74/12
162	14942	OMAHA	ND	41 18	95 54	60/ 1	64/12
163	14943	SIOUX CITY	IA	42 24	96 23	60/ 1	64/12
164	14944	SIOUX FALLS	SD	43 34	96 44	74/ 1	74/12
165	14949	OMAHA	NB	41 7	95 54	60/ 1	64/12
166	14991	EAU CLAIRE	WI	44 52	91 29	69/ 1	73/12
167	23002	ALAMOGORDO	NM	32 51	106 6	49/ 1	70/12
168	23009	ROSWELL/WALKER	NM	33 18	104 32	73/ 1	73/12
169	23023	MIDLAND	TX	31 56	102 12	60/ 1	64/12
170	23034	SAN ANGELO	TX	31 22	100 30	60/ 1	64/12
171	23039	LAS CRUCES	NM	32 22	106 29	51/ 1	55/12
172	23043	ROSWELL	NM	33 24	104 32	49/ 1	54/12
173	23044	EL PASO	TX	31 48	106 24	60/ 1	64/12
174	23047	AMARILLO	TX	35 14	101 42	55/ 1	64/12
175	23049	SANTA FE	NM	35 37	106 5	50/ 1	54/12
176	23052	RATON/CREWS	NM	36 45	104 30	49/ 1	51/12
177	23062	DENVER	CO	39 45	104 52	70/ 1	74/12
178	23064	GARDEN CITY	KS	37 56	100 43	50/ 1	54/12
179	23065	GOODLAND	KS	39 22	101 42	69/ 1	73/12
180	23066	GRAND JUNCTION	CO	39 7	108 12	60/ 1	64/12
181	23081	GALLUP	NM	35 31	108 47	73/ 1	75/12
182	23090	FARMINGTON	NM	36 45	108 14	54/ 1	64/12
183	23112	LAS VEGAS	NV	36 15	115 2	58/ 1	67/12
184	23114	EDWARDS	CA	34 54	117 52	66/ 1	70/12
185	23118	RENO/STEAD	NV	39 40	119 52	56/ 1	65/12
186	23122	SAN BERNARDINO	CA	34 6	117 14	66/ 1	70/12
187	23129	LONG BEACH	CA	33 49	118 9	49/ 1	64/12
188	23131	VICTORVILLE	CA	34 35	117 23	58/ 1	67/12
189	23136	OXNARD	CA	34 13	119 5	60/ 1	64/12
190	23152	BURBANK	CA	34 12	118 22	60/ 1	64/12
191	23154	ELY	NV	39 17	114 51	67/ 1	71/12
192	23155	BAKERSFIELD	CA	35 25	119 3	64/ 1	73/12
193	23158	BLYTHE	CA	33 37	114 43	69/ 9	74/ 8
194	23160	TUCSON	AZ	32 7	110 56	55/ 1	64/12
195	23161	DAGGET	CA	34 52	116 47	55/ 1	64/12
196	23169	LAS VEGAS	NV	36 5	115 10	60/ 1	64/12
197	23170	HANKSVILLE	UT	38 22	110 43	49/ 1	54/12
198	23174	LOS ANGELES	CA	33 56	118 24	55/ 1	64/12
199	23179	NEEDLES	CA	34 46	114 37	55/ 1	64/12
200	23183	PHOENIX	AZ	33 26	112 1	73/ 1	75/12

TABLE 6 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
201	23184	PRESCOTT	AZ	34 39	112 26	67/ 1	71/12
202	23185	RENO	NV	39 30	119 47	60/ 1	64/12
203	23188	SAN DIEGO	CA	32 44	117 1	65/ 1	74/12
204	23190	SANTA BARBARA	CA	34 26	119 50	60/ 1	64/12
205	23194	WINSLOW	AZ	35 1	110 44	49/ 1	54/12
206	23195	YUMA	AZ	32 40	114 36	67/ 1	71/12
207	23199	EL CENTRO	CA	32 49	115 41	54/ 1	58/12
208	23202	FAIRFIELD	CA	38 16	121 56	60/ 1	64/12
209	23211	SAN RAFAEL	CA	38 4	122 30	66/ 1	70/12
210	23230	OAKLAND	CA	37 44	122 12	60/ 1	64/12
211	23232	SACRAMENTO	CA	38 31	121 30	66/ 1	70/12
212	23234	SAN FRANCISCO	CA	37 37	122 23	69/ 1	73/12
213	23236	SANTA MARIA	CA	34 56	120 25	49/ 1	53/12
214	23239	ALAMEDA	CA	37 48	122 18	60/ 1	64/12
215	23244	SUNNYVALE	CA	37 25	122 4	60/ 1	64/12
216	23245	MONTERY	CA	36 35	121 52	59/ 1	63/12
217	23273	SANTA MARIA	CA	34 54	120 27	65/ 1	74/12
218	23275	UKIAH	CA	38 8	123 12	55/ 1	64/12
219	24012	DICKINSON	ND	46 47	102 48	60/ 1	64/12
220	24013	MINOT	ND	48 16	101 17	67/ 1	71/12
221	24015	AKRON	CO	40 10	103 13	50/ 1	54/12
222	24023	NORTH PLATTE	NB	41 8	100 41	69/ 1	73/12
223	24025	PIERRE	SD	44 23	100 17	67/ 1	71/12
224	24028	SCOTTSBLUFF	NB	41 52	103 36	67/ 1	71/12
225	24036	LEWISTOWN	MT	47 3	109 27	67/ 1	71/12
226	24057	RAWLINS	WY	41 48	107 12	55/ 1	64/12
227	24090	RAPID CITY	SD	44 3	103 4	67/ 1	71/12
228	24101	OGDEN	UT	41 7	111 58	65/ 1	69/12
229	24106	MT HOME	ID	43 3	115 52	65/ 1	69/12
230	24110	MOSES LAKE	WA	47 12	119 19	61/ 1	65/12
231	24118	FT BRIDGER	WY	41 24	110 25	50/ 1	54/12
232	24121	ELKO	NV	40 50	115 47	69/ 1	73/12
233	24128	WINNEMUCCA	NV	40 54	117 43	69/ 1	73/12
234	24130	BAKER	OR	44 50	117 49	60/ 1	64/12
235	24131	BOISE	ID	43 34	116 13	74/ 1	74/12
236	24135	BUTTE	MT	45 57	112 30	56/ 1	60/12
237	24137	CUTBANK	MT	48 36	112 22	49/ 1	58/12
238	24141	EPHRATA	WA	47 19	119 31	50/ 1	54/12
239	24144	HELENA	MT	46 36	112 0	58/ 1	62/12
240	24145	IDAHO FALL	ID	43 31	112 4	55/ 1	64/12

TABLE 6 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
241	24146	KALISPELL	MT	48 18	114 16	60/ 1	72/12
242	24151	MALAD CITY	ID	42 10	112 19	48/ 1	54/12
243	24153	MISSOULA	MT	46 55	114 5	67/ 1	71/12
244	24155	PENDLETON	OR	45 51	118 61	55/ 1	64/12
245	24156	POCATELLO	ID	42 55	112 36	65/ 1	74/12
246	24157	SPOKANE	WA	47 38	117 32	74/ 1	74/12
247	24160	WALLA WALLA	WA	46 6	118 17	50/ 1	54/12
248	24203	EVERETT	WA	47 55	122 17	63/ 1	67/12
249	24207	TACOMA	WA	47 9	122 29	66/ 1	70/12
250	24217	BELLINGHAM	WA	48 48	122 32	74/ 1	74/12
251	24219	DALLESPORT	WA	45 37	121 9	64/ 1	64/12
252	24220	ELLENSBURG	WA	47 2	120 31	50/ 1	54/12
253	24221	EUGENE	OR	44 7	123 13	74/ 1	74/12
254	24225	MEDFORD	OR	42 22	122 52	70/ 1	74/12
255	24227	OLYMPIA	WA	46 58	122 54	74/ 1	74/12
256	24229	PORTLAND	OR	45 36	122 36	69/ 1	73/12
257	24230	REDMON	OR	44 16	121 9	55/ 1	64/12
258	24232	SALEM	OR	44 55	123 1	74/ 1	74/12
259	24233	SEATTLE	WA	47 27	122 18	74/ 1	74/12
260	24234	SEATTLE	WA	47 32	122 18	60/ 1	64/12
261	24241	TOLEDO	WA	46 29	122 48	50/ 1	54/12
262	24243	YAKIMA	WA	46 34	120 32	74/ 1	74/12
263	24283	ARCATA	CA	40 59	124 6	60/ 1	72/12
264	93026	DOUGLAS	AZ	31 27	109 36	50/ 1	54/12
265	93034	HOBBS	NM	32 41	103 12	49/ 1	54/12
266	93037	COLO SPRINGS	CO	38 49	104 43	74/ 1	74/12
267	93044	ZUNI	NM	35 6	108 48	67/ 1	71/12
268	93057	GRANTS	NM	35 10	107 54	54/ 1	54/12
269	93102	FALLON	NV	39 25	118 43	66/ 1	70/12
270	93106	LOS ALAMITOS	CA	33 48	118 7	65/ 1	69/12
271	93111	POINT MUGU	CA	34 7	119 7	52/ 3	72/ 2
272	93112	SAN DIEGO	CA	32 43	117 12	67/ 1	71/12
273	93214	VANDENBERG	CA	34 43	120 34	59/ 1	72/12
274	93706	HAGERSTOWN	MD	39 42	77 43	74/ 1	74/12
275	93733	FT MEADE	MD	39 5	76 46	60/ 1	64/12
276	93739	WALLOPS IS	VA	37 51	75 29	69/ 1	73/12
277	93804	SPARTANBURG	SC	34 55	81 57	57/ 1	61/12
278	93805	TALLAHASSEE	FL	30 23	84 22	72/ 1	76/12
279	93807	WINSTON SALEM	NC	36 8	80 14	60/ 1	64/12
280	93815	DAYTON	OH	39 54	84 13	70/ 1	74/12

TABLE 6 (Concluded)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
281	93817	EVANSVILLE	IN	38 3	87 32	70/ 1	74/12
282	93819	INDIANAPOLIS	IN	39 44	86 17	55/ 1	74/12
283	93820	LEXINGTON	KY	38 2	84 36	55/ 1	64/12
284	93822	SPRINGFIELD	IL	39 50	89 40	70/ 1	74/12
285	93824	CAMBRIDGE	OH	39 57	81 54	50/ 1	54/12
286	93836	BRUNSWICK	GA	31 15	81 28	69/ 1	73/12
287	93841	MILTON	FL	30 42	87 1	62/ 1	71/12
288	93842	COLUMBUS	GA	32 31	84 56	69/ 1	73/12
289	93846	ANDERSON	SC	34 30	82 43	54/ 1	58/12
290	93919	MCCOMB	MS	31 15	90 28	49/ 1	54/12
291	93950	MCALESTER	OK	34 53	95 47	54/ 1	54/12
292	93987	LUFKIN	TX	31 14	94 45	67/ 1	71/12
293	93989	QUINCY	IL	39 56	91 12	50/ 1	54/12
294	93992	ELDORADO	AR	33 13	92 48	50/ 1	54/12
295	94012	HAVRE CITY	MT	48 33	109 46	67/ 1	71/12
296	94014	WILLISTON	ND	48 11	103 38	67/ 1	71/12
297	94224	ASTORIA	OR	46 9	123 53	74/ 1	74/12
298	94225	HOQUIAM	WA	46 58	123 56	54/ 1	58/12
299	94240	QUILLAYUTE	WA	47 57	124 33	74/ 1	74/12
300	94725	MASSENA	NY	44 56	74 51	70/ 1	74/12
301	94741	TETERBORO	NJ	40 51	74 3	52/ 1	56/12
302	94745	WHITE PL	NY	41 4	73 43	68/ 1	72/12
303	94746	WORCHESTER	MA	42 16	71 52	70/ 1	74/12
304	94789	NEW YORK	NY	40 47	73 46	74/ 1	74/12
305	94790	WATERTOWN	NY	44 0	76 1	60/ 1	64/12
306	94794	UTICA	NY	43 9	75 23	50/ 1	54/12
307	94822	ROCKFORD	IL	42 12	89 6	70/ 1	74/12
308	94830	TOLEDO	OH	41 36	83 48	70/ 1	74/12
309	94836	GWINN	MI	46 21	87 24	63/ 1	67/12
310	94846	CHICAGO	IL	41 59	87 54	70/ 1	74/12
311	94910	WATERLOO	IA	42 33	92 24	60/ 1	64/12

TABLE 8. LOCATION OF SPECIFIC POINT SOURCES AND SELECTED STAR DISPERSION DATA STATION

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
1	AIR PRODUCTS	PENSACOLA, FL	30 36 29	87 8 12	3855
2	AKZONA	MCCOOK, IL	41 48 17	87 49 41	94846
3	AKZONA	MORRIS, IL	41 24 24	88 18 10	14855
4	ALLIED	DANVILLE, IL	40 8 30	87 33 45	14806
5	ALLIED	ELIZABETH, NJ	40 40 45	74 13 51	4739
6	ALLIED	EL SEGUNDO, CA	33 56 30	118 26 35	23129
7	ALLIED	FRANKFORD, PA	40 18 15	79 52 43	14762
8	ALLIED	HOPEWELL, VA	37 22 13	77 18 8	13740
9	ALLIED	MOUNDSVILLE, WV	39 54 39	80 44 49	13736
10	ALLIED	SOUTHPOINT, OH	38 25 43	82 36 0	93824
11	AMAX	PORT NICKEL, LA	29 52 35	89 57 26	12958
12	AMER CYANAMID	BOUND BROOK, NJ	40 24 45	74 33 40	94741
13	AMER CYANAMID	CHARLOTTE, NC	35 12 16	80 50 32	13881
14	AMER CYANAMID	WILLOW ISLAND, WV	39 21 50	81 18 50	13736
15	AMER. HOECHST	BATON ROUGE, LA	30 33 2	191 15 50	13970
16	AMER PETROFINA	BIG SPRINGS, TX	32 17 10	101 25 17	13962
17	AMER PETROFINA	PORT ARTHUR, TX	29 57 30	93 53 20	12917
18	AMOCO	COPPER RIVER, SC	32 45 57	79 58 28	13717
19	AMOCO	DECATUR, AL	34 36 12	86 58 42	13882
20	AMOCO	JOLIET, IL	41 26 46	88 10 41	14855
21	AMOCO	TEXAS CITY, TX	29 21 40	94 55 50	12906
22	ARCO	CHANNELVIEW, TX 2	95 0 40	950 64 31	29060
23	ARCO	HOUSTON, TX	29 42 17	95 16 1	12960
24	ASHLAND	CATLETTSBURG, KY	38 22 39	82 35 58	13866
25	ASHLAND	FORD, NJ	40 31 20	74 20 50	4739
26	ASHLAND	JANESVILLE, WI	42 41 56	89 0 10	14839
27	BASF WYANDOTTE	GEISMAR, LA	30 11 34	91 0 42	13970
28	ASHLAND	N. TONAWANDA, NY 4	25 94 50	785 52 71	47470
29	BASF WYANDOTTE	KEARNEY, NJ	40 45 53	74 9 3	4739
30	BASF WYANDOTTE	WASHINGTON, NJ	40 45 20	74 58 22	4739
31	BASF WYANDOTTE	WYANDOTTE, MI	42 12 55	83 8 35	14822
32	BETHLEHEM STEEL	SPARROWS POINT, MD	39 18 30	76 34 30	13701
33	BLUE SPRUCE	BOUND BROOK, NJ	40 32 10	74 29 18	14737
34	BORDEN	DEMOPOLIS, AL	32 30 48	27 50 6	13850
35	BORDEN	DIBOLL, TX	31 11 52	94 46 50	93987
36	BORDEN	FAYETTEVILLE, NC	35 1 43	78 51 41	13714
37	BORDEN	FREMONT, CA	37 32 6	121 57 24	23244
38	BORDEN	GEISMAR, LA	30 13 0	91 1 0	13970
39	BORDEN	KENT, WA	47 23 12	122 13 15	24233
40	BORDEN	LA GRANDE, OR	45 20 33	100 2 2	24130

TABLE 8 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
41	BORDEN	LOUISVILLE, KY	38 12 9	85 51 49	93820
42	BORDEN	MISSOULA,MT	46 54 10	114 40 0	24146
43	BORDEN	SHEBOYGAN, WI	43 45 26	87 46 17	14898
44	BORDEN	SPRINGFIELD, OR	44 2 60	122 59 6	24221
45	BORG-WARNER	MORGANTOWN, WV	39 40 39	80 58 34	13736
46	BRUSH WELLMAN	ELMORE, OH	41 28 6	83 16 37	94830
47	BRUSH WELLMAN	HAMPTON, NJ	40 42 32	74 57 41	94741
48	BRUSH WELLMAN	READING, PA	40 46 45	76 11 10	14712
49	E.R.CARPENTER	BAY PORT, TX	29 43 20	94 54 0	12906
50	CELANESE	BAY CITY, TX	28 51 45	96 1 0	12923
51	CELANESE	BISHOP, TX	27 34 6	97 49 27	12925
52	CELANESE	CLEAR LAKE, TX	29 37 17	95 3 51	12906
53	CELANESE	LINDEN, NJ	40 37 18	74 15 53	94741
54	CELANESE	LOUISVILLE, KY	38 11 0	85 50 0	93820
55	CELANESE	NEWARK, NJ	40 43 30	74 7 25	94741
56	CELANESE	ROCK HILL, SC	34 57 25	80 57 32	93804
57	CHARTER OIL	HOUSTON, TX	29 42 50	95 15 12	12906
58	CHEMBOND	SPRINGFIELD, OR	44 2 60	122 59 6	24221
59	CHEMBOND	WINNIFIELD, LA	31 54 49	92 40 35	13942
60	CHEMTRON	LAPORTE, TX	29 39 20	95 2 18	12906
61	CHEVRON	PASCAGOULA, MS	30 19 4	88 28 37	13820
62	CHEVRON	RICHMOND, CA	37 56 12	122 20 48	23239
63	CIBA-GEIGY	TOMS RIVER, NJ	39 59 20	74 22 33	14706
64	CLARK	BLUE ISLAND, IL	41 39 21	87 41 56	14855
65	COASTAL STATES	CORPUS CHRISTI, TX	27 48 43	97 26 28	12925
66	CONTINENTAL	CLIFTON, NJ	40 43 34	74 7 26	94741
67	CONTINENTAL	NEWARK, NJ	40 43 34	74 7 26	94741
68	COS-MAR	CARVILLE, LA	30 13 30	91 4 0	13970
69	CPC	LYNDHURST, NJ	40 47 30	74 4 34	94741
70	CROWLY TAR	HOUSTON, TX	29 43 50	95 14 20	12906
71	CROWN OIL	PASADENA, TX	29 44 40	95 10 30	12906
72	DEGUSSA	THEODORE, AL	30 33 6	88 10 35	3855
73	DENKA	HOUSTON, TX	29 41 31	95 15 12	12906
74	DIAMND SHAMROCK	BELLE, WV	38 14 9	81 32 38	13866
75	DOW	FREEPORT, TX	28 59 30	95 23 35	12923
76	DOW	MIDLAND, MI	43 35 28	84 13 8	14845
77	DOW	PITTSBURG, CA	37 59 34	121 54 56	23202
78	DOW	PLAQUEMINE, LA	30 19 0	91 15 0	13970
79	DU PONT	ANTIOCH, CA	37 59 37	121 52 0	23202
80	DU PONT	BEAUMONT, TX	30 0 51	94 1 40	12917

TABLE 8 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
81	DU PONT	BELLE, WV	38 13 6	81 34 12	13866
82	DU PONT	CORPUS CHRISTI, TX	27 53 0	97 15 0	12925
83	DU PONT	DEEPWATER, NJ	39 41 25	75 30 35	13739
84	DU PONT	GIBBSTOWN, NJ	39 49 50	75 15 50	13739
85	DU PONT	HEALING SPRING, NC	35 1 56	80 10 30	13714
86	DU PONT	HOUSTON, TX	29 42 4	95 2 5	12906
87	DU PONT	LAPLACE, LA	30 4 0	90 32 0	12958
88	DU PONT	LAPORTE, TX	29 42 4	95 2 5	12906
89	DU PONT	LINDEN, NJ	40 36 2	74 12 8	94741
90	DU PONT	LOUISVILLE, KY	38 11 51	85 54 13	13807
91	DU PONT	MONTAGUE, MI	43 24 10	86 23 40	14840
92	DU PONT	OLD HICKORY, TN	36 16 24	86 34 12	13897
93	DU PONT	PARKERSBURG, WV	39 15 27	81 32 52	13866
94	DU PONT	TOLEDO, OH	41 39 22	83 33 20	94830
95	DU PONT	VICTORIA, TX	28 40 29	96 57 21	12923
96	DU PONT	WILMINGTON, NC	34 10 0	77 56 6	13717
97	EASTMAN KODAK	COLUMBIA, SC	33 59 50	81 4 17	13744
98	EASTMAN KODAK	KINGSPORT, TN	36 31 41	82 12 22	13877
99	EASTMAN KODAK	LONGVIEW, TX	32 25 55	94 41 6	13972
100	EASTMAN KODAK	ROCHESTER, NY	43 12 1	77 37 58	14771
101	EMERY	MAULDIN, SC	34 48 16	82 16 9	93804
102	EMERY	SANTAFE SPRINGS, CA	33 55 30	118 5 40	23174
103	ETHYL	BATON ROUGE, LA	30 18 0	91 8 0	13970
104	EXXON	BATON ROUGE, LA	30 9 10	90 54 20	13970
105	EXXON	BAYTOWN, TX	29 44 50	95 1 0	12906
106	EXXON	BAYWAY, NJ	40 38 46	74 11 48	94741
107	FALLEK	TUSCALOOSA, AL	33 11 0	87 34 50	93806
108	FERRO	SANTA FE S. , CA	33 56 30	118 4 10	93106
109	FIRST CHEMICAL	PASCAGOULA, MS	30 21 20	88 32 55	13820
110	FMC	BALIMORE, MD	39 14 50	76 35 30	13701
111	FMC	BUFFALO, NY	42 59 10	78 50 30	14747
112	FMC	MIDDLEPORT, NY	43 12 21	78 29 23	14747
113	FMC	NITRO, WV	38 25 33	81 50 5	13866
114	FMC	SO CHARLESTON, WV	38 22 10	81 40 3	13866
115	GAF	CALVERT CITY, KY	37 2 50	88 21 12	3816
116	GAF	LINDEN, NJ	40 38 19	74 15 26	94741
117	GAF	TEXAS CITY, TX	29 25 29	94 58 7	12923
118	GEN ELECTRIC	MOUNT VERNON, IN	37 56 42	87 34 25	93817
119	GEORGIA-PACIFIC	ALBANY, OR	44 37 7	123 5 13	24232
120	GEORGIA-PACIFIC	COLUMBUS, OH	39 53 7	82 56 45	14821

TABLE 8 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
121	GEORGIA-PACIFIC	COOS BAY, OR	42 27 26	124 10 47	24283
122	GEORGIA-PACIFIC	CROSSETT, AR	33 8 36	93 2 11	93992
123	GEORGIA-PACIFIC	LUFKIN, TX	31 21 0	94 47 0	93987
124	GEORGIA-PACIFIC	PLAQUEMINE, LA	30 15 0	91 11 0	13970
125	GEORGIA-PACIFIC	RUSSELVILLE, SC	33 20 52	79 58 0	13717
126	GEORGIA-PACIFIC	TAYLORVILLE, MS	31 51 0	89 25 0	13865
127	GEORGIA-PACIFIC	VIENNA, GA	32 7 30	83 49 0	13815
128	GETTY OIL	EL DORADO, KS	37 47 10	96 52 0	13969
129	W. R. GRACE	NASHUA, NH	42 46 0	71 27 52	14745
130	GULF	ALLIANCE, LA	29 50 0	90 0 19	12958
131	GULF	CEDAR BAYOU, TX	29 49 29	94 55 16	12923
132	GULF	JERSEY CITY, NJ	40 43 2	74 6 14	94741
133	GULF	PHILADELPHIA, PA	39 54 0	75 12 30	13739
134	GULF	VICKSBURG, MS	32 17 0	90 54 0	13956
135	HANNA MINING	RIDDLE, OR	42 55 2	123 25 0	24221
136	HERCULES	WILMINGTON, NC	34 19 27	77 46 56	13717
137	HERCULES	BRUNSWICK, GA	31 7 55	81 28 5	93836
138	HERCULES	HARBOR BEACH, MI	43 51 7	82 42 8	14845
139	HERCULES	HOPEWELL, VA	37 15 34	77 17 14	13740
140	HERCULES	LOUISIANA, MO	39 26 24	91 3 37	93989
141	HERCULES	PARLIN, NJ	40 31 30	74 27 10	94741
142	HERCULES	WILMINGTON, NC	34 19 9	77 59 23	13748
143	HEXCEL	LODI, NJ	40 52 0	74 6 50	94741
144	HIGHPOINT	HIGH POINT, NC	35 59 10	80 0 37	93807
145	HODAG	STOKIE, IL	42 1 50	87 43 39	14855
146	HOOKER	MONTAGUE, MI	43 24 45	86 22 30	14840
147	HOOKER	NIAGARA FALLS, NY	43 3 2	79 0 27	14747
148	HOOKER	N TONAWANDA, NY	43 2 47	78 51 44	14747
149	ICC	NIAGARA FALLS, NY	43 3 33	79 0 55	14747
150	IMC	SEIPLE, PA	40 38 12	75 31 38	14737
151	IMC	STERLINGTON, LA	32 43 25	92 8 56	13942
152	INTER MINERAL	TERRE HAUTE, IN	39 27 7	87 25 2	13806
153	JEFFERSON	AUSTIN, TX	30 20 0	97 14 15	13958
154	JEFFERSON	CONROE, TX	30 18 50	95 23 6	12960
155	JEFFERSON	PORT NECHES, TX	29 57 45	93 56 0	12917
156	JONES & LAUGHLI	ALIQUIPPA, PA	40 35 54	80 14 24	14762
157	KALAMA	EDDYSTONE, PA	39 50 58	75 20 0	13739
158	KALAMA	KALAMA, WA	46 0 54	122 51 5	24229
159	KAWECKI BERYLCO	HAZELTON, PA	40 21 28	75 57 10	14737
160	KAWECKI BERYLCO	READING, PA	40 47 32	76 11 50	14712

TABLE 8 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
161	H. KOHNSTAM	CAMDEN, NJ	39 54 42	75 8 53	13739
162	H. KOHNSTAM	CLEARING, IL	41 49 10	87 45 40	14855
163	KOPPERS	CICERO, IL	41 48 44	87 45 4	14855
164	KOPPERS	FOLLANSBEE, WV	40 23 10	80 35 7	14762
165	KOPPERS	OIL CITY, PA	41 29 30	79 43 20	14860
166	LACHAT	MEQUON, WI	43 13 56	88 2 30	14839
167	LONZA	MAPLETON, IL	40 34 0	89 43 1	14842
168	MAGNA	HOUSTON, TX	29 40 10	95 23 30	12906
169	MAK CHEMICAL	MUNCIE, IN	40 12 17	85 20 38	93815
170	MALLINCKRODT	LODI, NJ	40 52 56	74 5 46	94741
171	MERICHEM	HOUSTON, TX	29 45 36	95 10 48	12906
172	MILLIKEN	INMAN, SC	34 56 10	82 6 29	93804
173	MINEREC	BALTIMORE, MD	39 14 11	76 34 41	13701
174	3M	DECATUR, AL	34 38 39	87 2 25	13882
175	MOBAY	BAYTOWN, TX	29 45 30	94 54 25	12906
176	MOBAY	NEW MARTNSVILLE, WV	39 44 50	80 50 50	13736
177	MOBILE	BEAUMONT, TX	30 4 14	94 3 40	12917
178	MONSANTO	ADDYSTON, OH	39 7 30	84 42 58	93815
179	MONSANTO	ALVIN, TX	29 14 55	95 12 45	12906
180	MONSANTO	BRIDGEPORT, NJ	39 47 33	75 23 45	13739
181	MONSANTO	CHOCOLATE BAYOU, TX	29 14 55	95 12 45	12906
182	MONSANTO	EUGENE, OR	44 2 59	123 8 19	24221
183	MONSANTO	KEARNEY, NJ	40 46 12	74 9 8	94741
184	MONSANTO	LULING, LA	29 55 10	90 22 30	12958
185	MONSANTO	NITRO, WV	38 24 26	81 51 26	13866
186	MONSANTO	SAUGET, IL	38 35 31	90 10 11	13994
187	MONSANTO	SPRINGFIELD, MA	42 9 33	72 29 9	14763
188	MONSANTO	ST. LOUIS, MO	38 34 37	90 11 42	13994
189	MONSANTO	TEXAS CITY, TX	29 22 45	94 33 30	12923
190	MONTROSE	HENDERSON, NV	36 3 32	114 58 34	23112
191	MONTROSE	TORRANCE, CA	33 46 58	118 22 6	23129
192	NALCO	SUGAR LAND, TX	29 37 10	95 28 32	12906
193	NAPP	LODI, NJ	40 52 30	74 6 14	94741
194	NATIONAL STARCH	SALISBURY, NC	35 43 36	80 28 19	13723
195	NEPARA	HARRIMAN, NY	41 16 45	74 8 24	14757
196	NORDA	BOONTON, NJ	40 54 13	74 24 44	94741
197	N PETROCHEMICAL	EAST MORRIS, IL	41 24 8	88 17 18	94846
198	OCCIDENTAL	N TONAWANDA, NY	43 2 47	78 51 44	14747
199	OLIN	ASHTABULA, OH	41 53 7	80 45 50	14843
200	OLIN	BRANDENBURG, KY	38 0 27	86 6 50	13807

TABLE 8 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
201	OLIN	LAKE CHARLES, LA	30 13 55	93 15 57	3937
202	ORBIS	NEWARK, NJ	40 41 16	74 12 17	94741
203	OWENS-CORNING	NEWARK, OH	40 5 30	82 26 0	93824
204	OXIRANE	BAYPORT, TX	29 37 26	95 3 7	12906
205	OXIRANE	CHANNELVIEW, TX	29 48 50	95 7 30	12906
206	PACIFIC RESINS	EUGENE, OR	44 1 0	123 5 5	24221
207	PBI-GORDON	KANSAS CITY, MO	39 8 53	94 40 59	13988
208	PELRON	LYONS, IL	41 44 56	87 49 4	94846
209	PENNWALT	CALVERT CITY, KY	37 3 18	88 19 40	3816
210	PERSTORP	TOLEDO, OH	41 43 10	83 31 28	94830
211	PETROLITE	BREA, CA	33 53 30	117 58 45	23174
212	PETROLITE	ST LOUIS, MO	38 41 50	90 12 0	13994
213	PFIZER	TERRE HAUTE, IN	39 26 1	87 24 22	93819
214	PLASTICS ENG	SHEBOYGAN, WI	43 45 0	87 47 0	14839
215	PPG	BARBERTON, OH	41 0 37	81 36 29	14895
216	PPG	BEAUMONT, TX	30 3 40	94 2 30	12917
217	PPG	CIRCLEVIEW, OH	39 36 5	82 57 34	93824
218	PPG	LAKE CHARLES, LA	30 13 14	93 16 54	3937
219	PPG	NEW MARTNSVILLE, WV	39 47 22	80 51 27	13736
220	PROCTR & GAMBLE	MEMPHIS, TN	35 10 40	89 56 30	13963
221	PUBLICKER	PHILADELPHIA, PA	39 53 30	75 12 18	13739
222	QUAKER OATS	MEMPHIS, TN	35 10 30	89 56 56	13963
223	QUINTANA-HOWELL	CORPUS CHRISIT, TX	27 48 35	97 27 30	12925
224	REICHHOLD	ANDOVER, MA	42 8 30	71 8 28	14739
225	REICHHOLD	AZUSA, CA	34 7 52	117 53 51	23174
226	REICHHOLD	CARTERET, NJ	40 35 56	74 13 13	94741
227	REICHHOLD	DETROIT, MI	42 28 17	83 7 52	14822
228	REICHHOLD	HAMPTON, SC	32 53 33	81 6 10	3820
229	REICHHOLD	HOUSTON, TX	29 45 10	95 10 15	12906
230	REICHHOLD	KANSAS CITY, KS	39 9 28	94 37 41	13988
231	REICHHOLD	MALVERN, AR	34 24 9	92 48 45	13963
232	REICHHOLD	MONCURE, NC	35 31 18	79 4 52	13714
233	REICHHOLD	TACOMA, WA	47 16 11	122 22 57	24207
234	REICHHOLD	TUSCALOOSA, AL	33 12 3	87 34 0	13825
235	REICHHOLD	WHITE CITY, OR	42 26 18	122 7 7	24225
236	REILLY TAR	INDIANAPOLIS, IN	39 42 0	86 14 0	93819
237	RIVERDALE	CHICAGO HEIGHT, IL	41 30 30	87 38 11	94846
238	ROHM & HAAS	DEER PARK, TX	29 43 30	95 6 15	12906
239	ROHM & HAAS	PHILADELPHIA, PA	39 54 50	75 11 30	13739
240	RUBICON	GEISMAR, LA	30 12 0	91 11 30	12958

TABLE 8 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
241	SCHENECTADY	OYSTER CREEK, TX	29 58 21	95 20 38	12960
242	SCHENECTADY	ROTTERDAM JUNC, NY	42 47 22	73 43 12	14735
243	SCHER BROTHERS	CLIFTON, NJ	40 42 14	74 10 17	94741
244	SHELL	DEER PARK, TX	29 42 55	95 7 34	12906
245	SHELL	GEISMAR, LA	30 11 0	90 59 0	12958
246	SHELL	MARTINEZ, CA	38 0 5	122 6 40	23202
247	SHELL	NORCO, LA	30 0 11	90 23 42	12958
248	SHELL	ODESSA, TX	31 49 14	102 19 53	23023
249	SHEREX	JANESVILLE, WI	42 40 47	89 0 30	14837
250	SHERWIN WILLIAM	CHICAGO, IL	41 43 4	87 36 30	94846
251	SPECIALTY ORGAN	IRWINDALE, CA	34 6 30	117 55 48	23152
252	STANDARD	RICHMOND, TX	37 56 12	122 20 48	12906
253	STAND CHLORINE	DELAWARE CITY, DE	39 33 54	75 38 47	94741
254	STAUFFER	COLD CREEK, AL	30 58 30	88 1 16	93841
255	STAUFFER	GALLIPOLIS FY., WV	38 46 40	82 10 54	13866
256	STAUFFER	EDISON, NJ	40 29 23	74 23 3	94741
257	STAUFFER	LEMOYNE, AL	30 53 50	87 58 50	93841
258	STAUFFER	LOUISVILLE, KY	38 12 9	85 51 49	93820
259	STEPAN	MILLSDALE, IL	41 26 3	88 9 48	94846
260	STERLING	CINCINNATI, OH	39 5 15	84 33 9	13840
261	STINSON	ANACORTES, WA	48 28 31	122 32 48	24217
262	SUN OIL	CLAYMONT, DE	39 48 20	75 25 40	94741
263	SUN OIL	CORPUS CHRISTI, TX	27 50 0	97 31 25	12925
264	SUN OIL	MARCUS HOOK, PA	39 48 45	75 24 51	13739
265	SUN OIL	TOLEDO, OH	41 36 52	83 31 40	94830
266	SUN OIL	TULSA, OK	36 8 18	96 1 18	13968
267	TELEDYNE MCCORM	HOLLISTER, CA	36 50 6	121 25 0	2324
268	TENN EASTMAN	KINGSPORT, TN	36 31 27	88 32 29	3816
269	TENNECO	CHALMETTE, LA	30 3 30	89 58 30	12958
270	TENNECO	FORDS, NJ	40 30 50	74 19 17	94741
271	TENNECO	GARFIELD, NJ	40 52 28	74 6 47	94741
272	TEXAS EASTMAN	LONGVIEW, TX	32 25 55	94 41 6	13972
273	TOMS RIVER	TOMS RIVER, NJ	39 58 14	74 12 30	14706
274	UNION CARBIDE	AMBLER, PA	40 1 48	75 13 41	13739
275	UNION CARBIDE	BOUND BROOK, NJ	40 33 32	74 31 18	94741
276	UNION CARBIDE	FREMONT, CA	37 28 38	122 0 40	23244
277	UNION CARBIDE	INSTITUTE, WV	38 23 2	81 47 24	13866
278	UNION CARBIDE	SEADRIFT, TX	28 30 31	96 46 18	12923
279	UNION CARBIDE	SO CHARLESTON, WV	38 19 35	81 40 29	13866
280	UNION CARBIDE	ST. JOSEPH, MO	39 45 36	94 50 46	13921

TABLE 8 (Concluded)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
281	UNION CARBIDE	TAFT, LA	29 58 0	90 27 0	13970
282	UNIROYAL	GEISMAR, LA	30 13 30	91 0 15	12958
283	UOP	E RUTHERFOLD, NJ	40 49 46	74 5 30	94741
284	UPJOHN	LAPORTE, TX	29 42 26	95 4 29	12906
285	U. S. STEEL	CLAIRTON, PA	40 18 15	79 52 43	14762
286	U. S. STEEL	HAVERHILL, OH	38 34 52	82 49 36	13866
287	US STEEL	GENEVA, VT	40 19 1	114 42 92	41010
288	VAN DE MARK	LOCKPORT, NY	43 11 8	78 42 40	14747
289	VELSICOL	BEAUMONT, TX	29 58 16	94 3 17	12917
290	VELSICOL	CHATTANOOGA, TN	35 2 31	85 16 36	13882
291	VELSICOL	MARSHALL, IL	39 23 0	87 42 30	93819
292	VELSICOL	MEMPHIS, TN	35 9 50	89 57 45	13963
293	VERTAC	JACKSONVILLE, AR	34 55 36	92 4 56	13963
294	VERTAC	WEST HELENA, AR	34 36 10	90 33 45	13939
295	VULCAN	GEISMAR, LA	30 10 0	90 59 0	12958
296	VULCAN	WICHITA, KA	37 36 55	97 18 30	13969
297	WITCO	CLEARING, IL	41 48 2	87 46 39	94846
298	WITCO	HOUSTON, TX	29 34 45	95 26 0	12906
299	WRIGHT	RIEGELWOOD, NC	34 19 22	78 12 9	13717

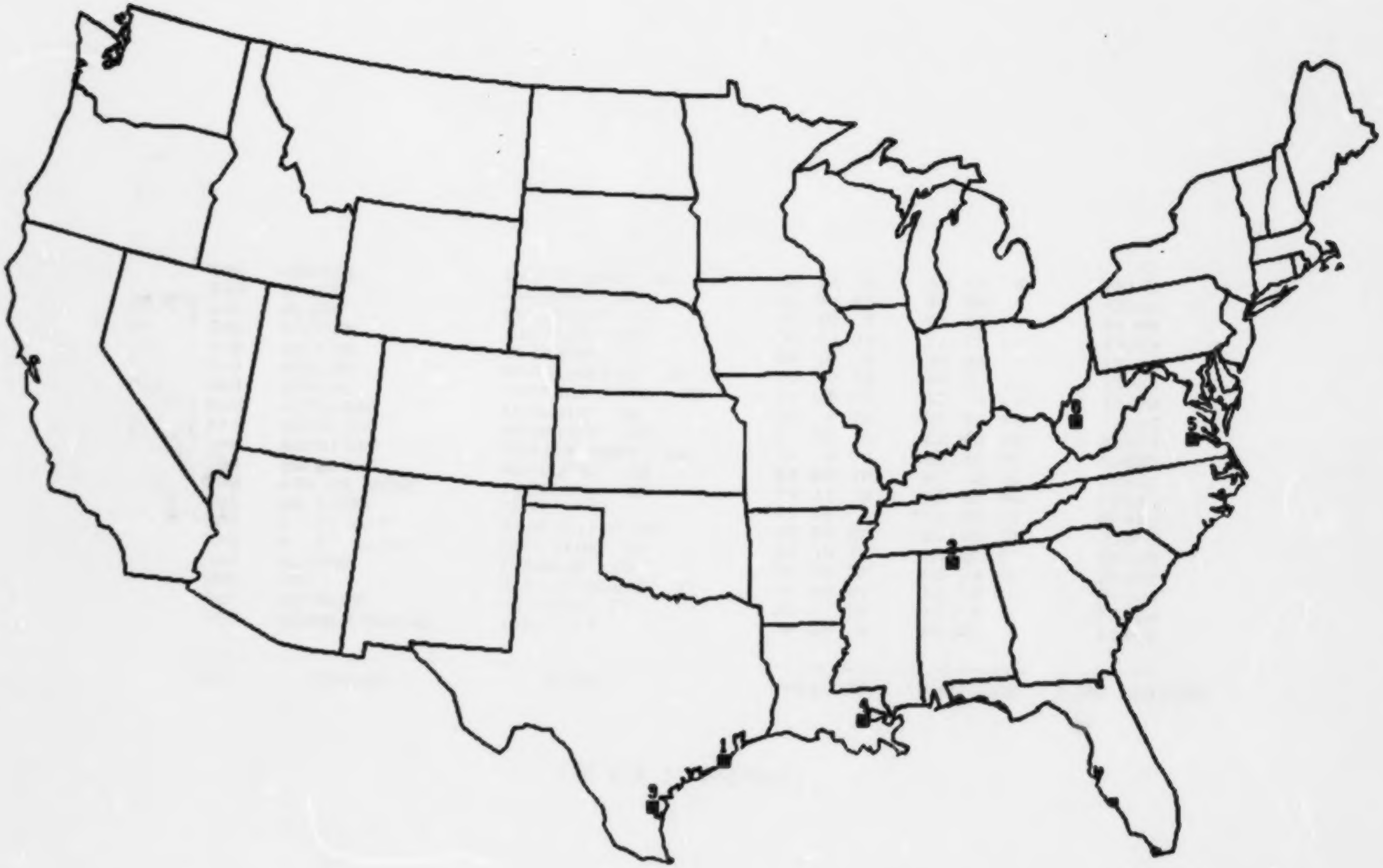

FIGURE 3. STAR STATION SELECTION PROCESS MAP I

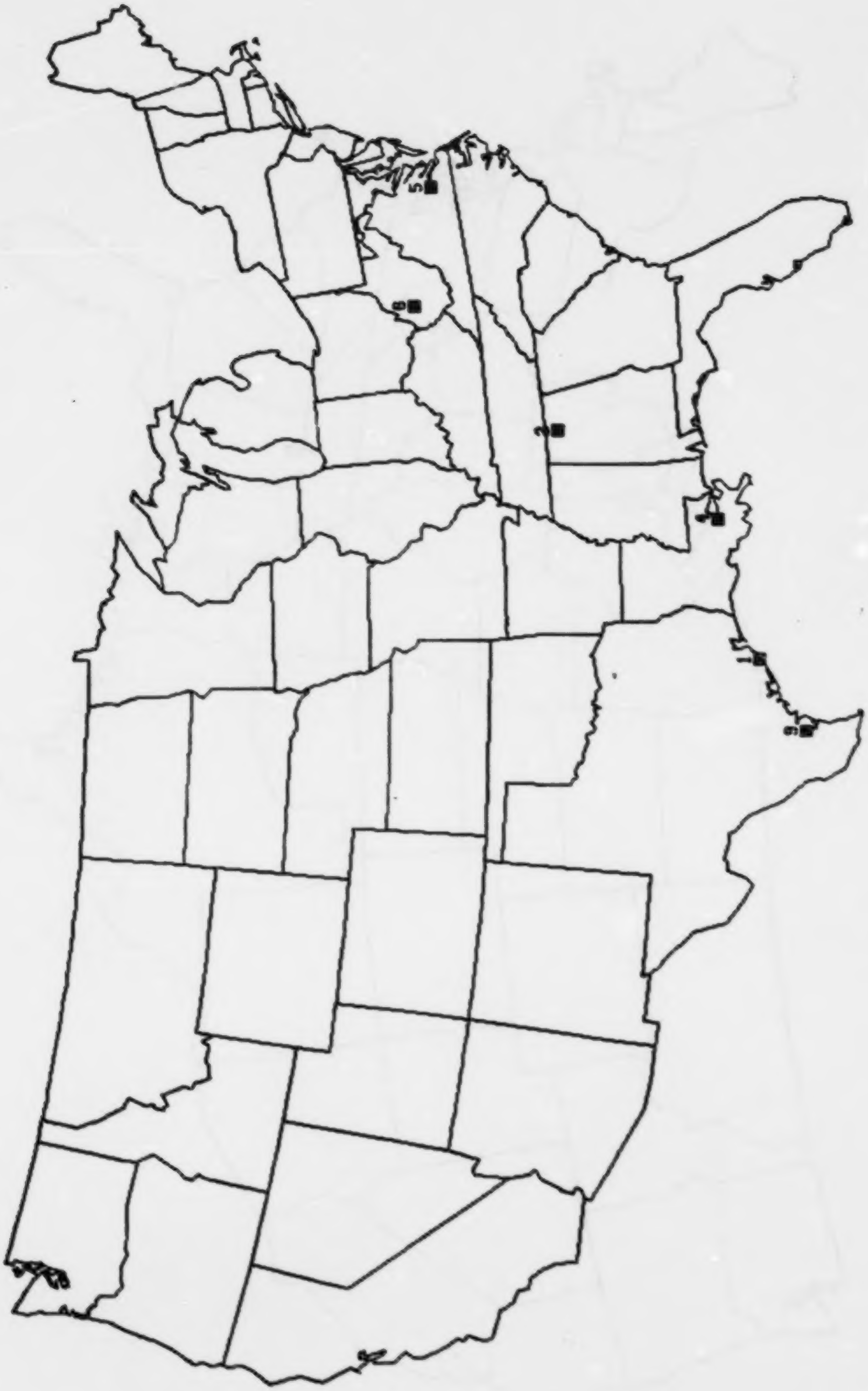

FIGURE 4. STAR STATION SELECTION PROCESS MAP II

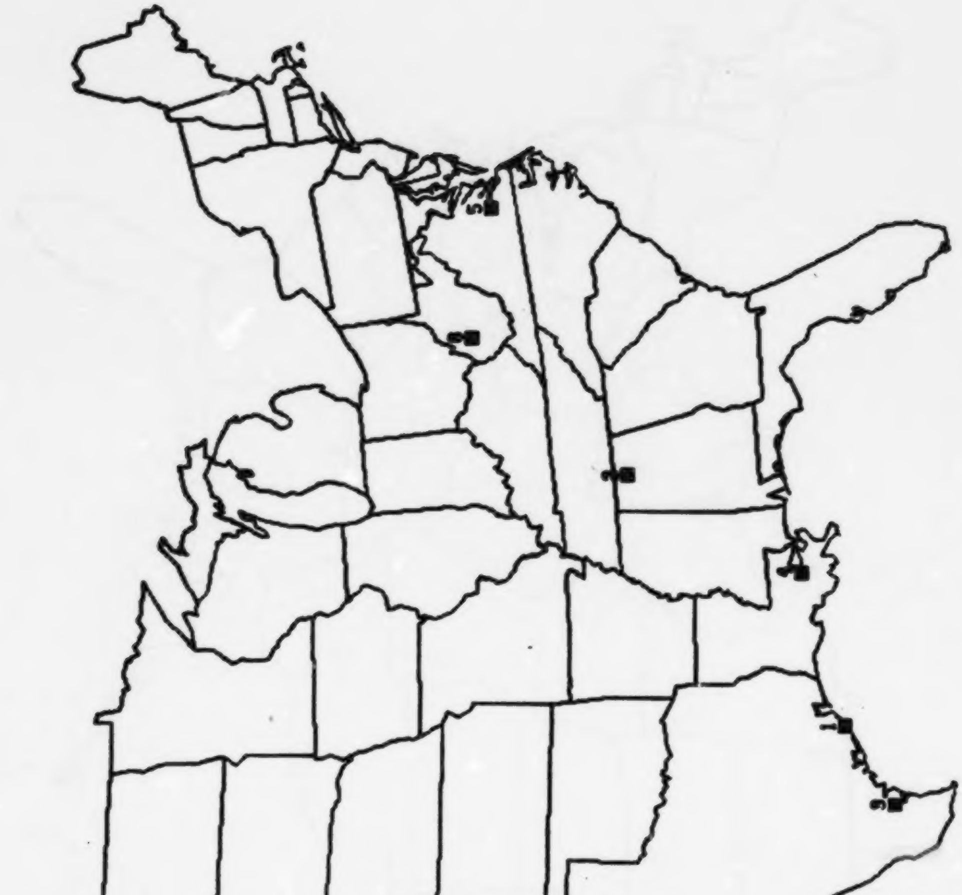

FIGURE 5. STAR STATION SELECTION PROCESS MAP III

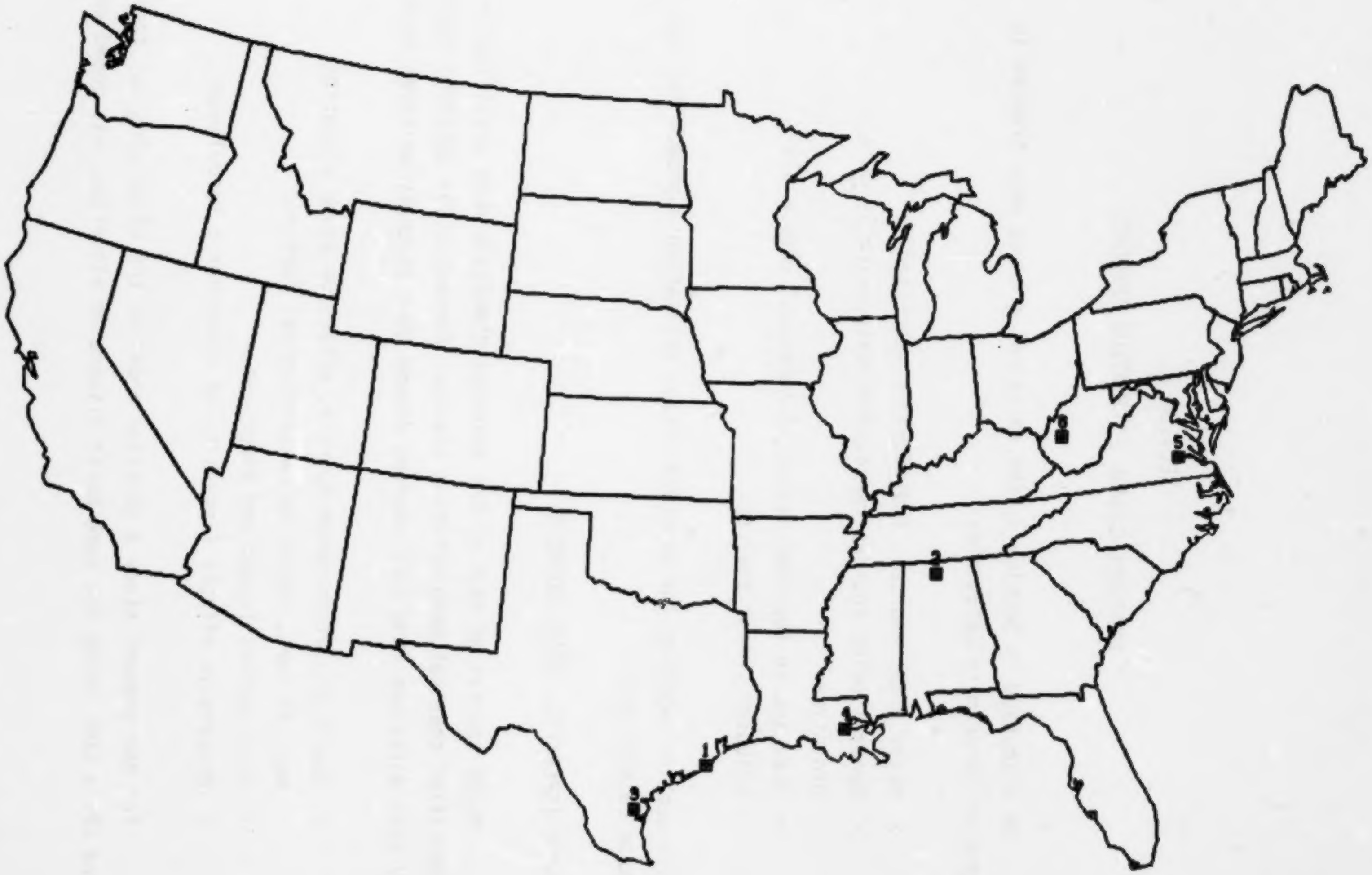

FIGURE 6. STAR STATION SELECTION PROCESS MAP IV

SECTION 3

EXPOSURE-DOSAGE ESTIMATION APPROACH

As discussed in Section 1, the emissions sources were treated in terms of three main categories:

> Major point sources, individually specified.
> General point sources represented categorically by a prototype.
> Area source representations of numerous, widely distributed, minor sources.

This section explains the exposure-dosage estimation approach for each of those categories.

MAJOR (SPECIFIC) POINT SOURCES

Major sources of most of the selected chemicals were specifically identified chemical manufacturing plants. Concentration patterns caused by unit emissions from such sources depend most strongly on three factors:

> Source elevation above terrain; effective plume elevation may, in turn, depend on meteorological factors.
> Wind vectors (speed and direction).
> Dispersive effects (intensity of atmospheric turbulence).

For the present study a Gaussian model in the climatological form of the EPA's CDM, using the same basic dispersion algorithm, was coded and used to estimate the annual average ground-level concentrations resulting from emissions from major point sources. It was necessary to plan for executing the model for up to 1000 major point sources and generic point sources, but much of the computer time required by comparable existing algorithms is used for repetitive evaluations of the Gaussian kernel. Because wind velocity and atmospheric stability are the only meteorological variables involved in the Gaussian dispersion estimation, the Gaussian kernel needs to be evaluated only 36 times (6 wind speeds times 6 stability classes) for a specific combination of source elevation and building cross-section. The Gaussian algorithms can be used to generate a file of normalized Gaussian solutions (concentration/emissions), one for each combination of wind speed and stability, so we computed and stored these Guassian concentration files for use in conjunction with STAR data, emissions data, and reactivity data, in estimating the annual average concentrations. Substantial computer savings were achieved through this "matrix modeling" approach.

In SAI's matrix modeling concept, the climatological Gaussian algorithm would be used to generate a file of normalized Gaussian solutions, one for each combination of wind speed and stability. This task is accomplished through evaluation of the function given by:

$$\left[\frac{\chi}{Q}(R)\right]_{ij} = \frac{\chi}{Q}(R,U_i,S_j) \quad , \tag{1}$$

where

χ = concentration,
Q = emissions rate,
U_i = i-th wind speed
S_j = j-th stability class,
R = travel distance from the source.

For reactive materials, this equation is extended to include a dependence on an exponential decay rate derived from prototype analysis:

$$\left[\frac{\chi}{Q}(R)\right]_{ijk} = \frac{\chi}{Q}(R, U_i, S_j, \tau_k) \quad , \qquad (2)$$

where τ_k is the half-life of the k-th species. With this computer file available, climatological concentration patterns are obtained by matrix multiplication with STAR* data:

$$\left[\frac{\chi}{Q}(R, \theta)\right]_k = \left[\frac{\chi}{Q}(R)\right]_{ijk} \phi(U_i, S_j, \theta) \quad . \qquad (3)$$

The maximum radius considered in the exposure/dosage estimation was set as 20 km for major point sources. Concentrations were estimated for 10 receptors--0.2, 0.3, 0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 15.0, and 20.0 km from the source--along each of the 16 wind directions. As shown in Table 13 for the example of chloroprene, there may be instances of more than one type of point source (each with its characteristic release height, emissions rate, etc.) within a single plant. For the case shown, fugitive emissions (valve and flange leaks, etc.) that are random and indeterminate but not negligible are approximated by a single source point 5 m above the ground. This is a height typical of outdoor plumbing. The building wake effect assures that the assumed point source is represented as a source with dimensions larger than the adjacent structure. Each emissions category was modeled individually, and the total ground-level concentrations resulting from plant emissions were then computed by summing the individual estimates.

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* STAR data are standard climatological frequency of occurrence summaries formatted for use in EPA models and available for major U.S. sites from the National Climatic Center, Asheville, North Carolina. The data consist of frequencies ϕ, tabulated as functions of wind speed, U_i; stability, S_j; and direction, θ.

The dispersion algorithm can also treat chemical formation and decay, enhanced dispersion caused by building wake effects, and release or stack height. These features are discussed in the following subsections.

Chemical Reactivity

The detailed approach adopted in estimating the effect of chemical reactions on ambient concentrations is shown with chloroprene as an example. Chloroprene is an organic compound that is decidedly photoreactive in the atmosphere. Based on preliminary calculations conducted with estimated decay rate, approximately 90 percent of the chloroprene emitted into the sunlit urban atmosphere would be removed within an hour through reaction with hydroxyl radicals and ozone molecules. However, the chemical decay rates are much lower in the nighttime or under overcast conditions. Figure 7 displays a comparison between the resulting concentrations along a single wind direction with and without the chemical decay computed for a chloroprene example.* Because the chemical reactions that change atmospheric concentrations occur over time, the chemical reactivity of a compound has less impact on the concentrations near the emissions source than further downwind. The difference in concentrations between

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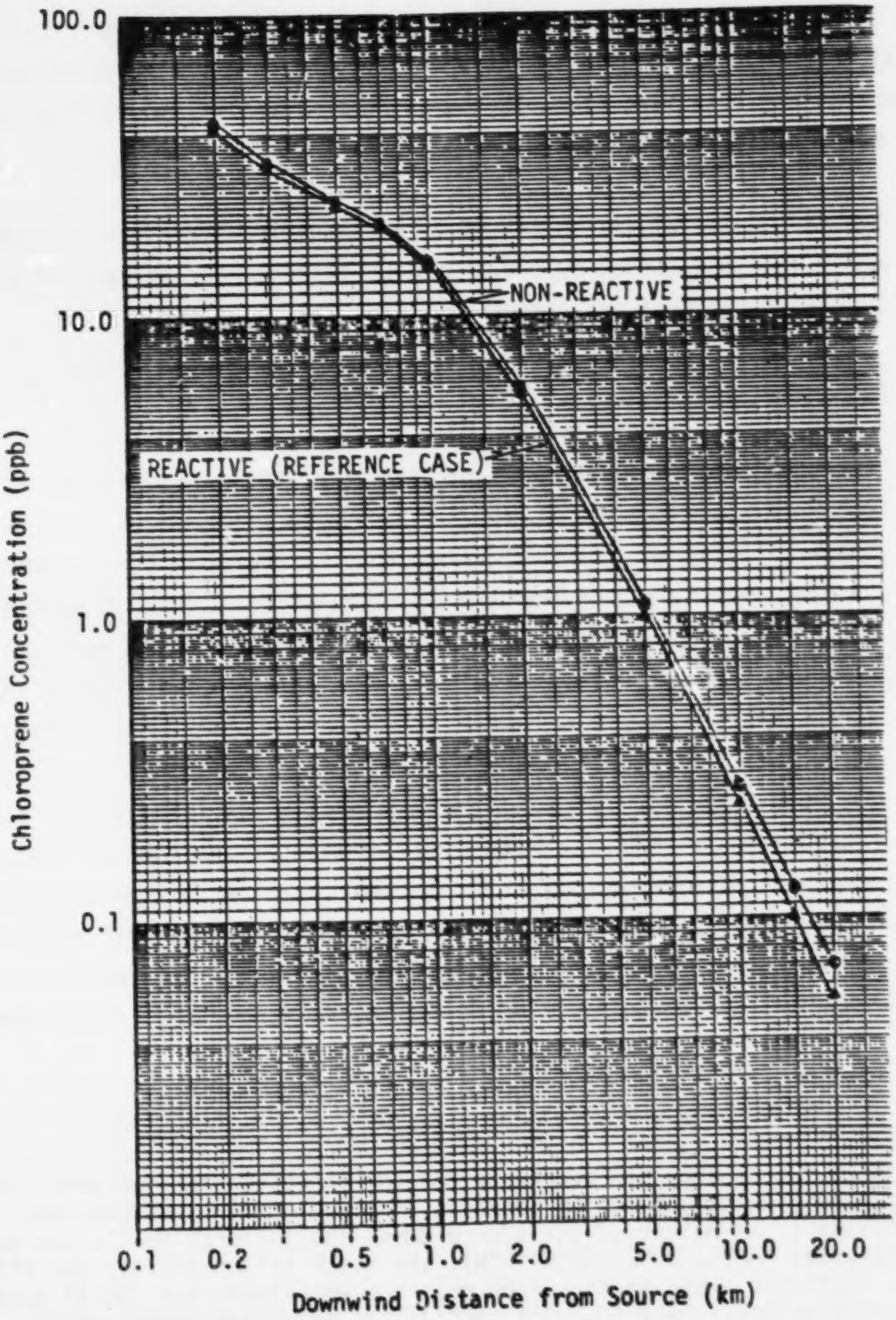
* The data inputs that are necessary for the reactive case include: the chloroprene emissions source location (the Dupont plant at Laplace, Louisiana); the nature of the source emissions (process vent); the map coordinates (90°32'00"W, 30°04'0"N); the stack height (20 m); the effective building cross section (100 m^2); the emissions rate (34.23 g/sec); the daytime decay rate (0.00058 sec^{-1}); the nighttime decay rate (0.000020 sec^{-1}); the wind direction (1, from the north); and the STAR station [12916 (New Orleans Muisant)].



Source: Systems Applications, Incorporated computations using SAI dispersion model and SAI reactivity estimates.

FIGURE 7. EFFECTS OF CHEMICAL REACTIVITY ON CONCENTRATION DISTRIBUTION OF CHLOROPRENE

the two curves of Figure 7 at 200 meters from the source is about 3 percent (43.2/41.9 - 1); at 20 km from the source the difference is about 30 percent (0.070/0.054 - 1).

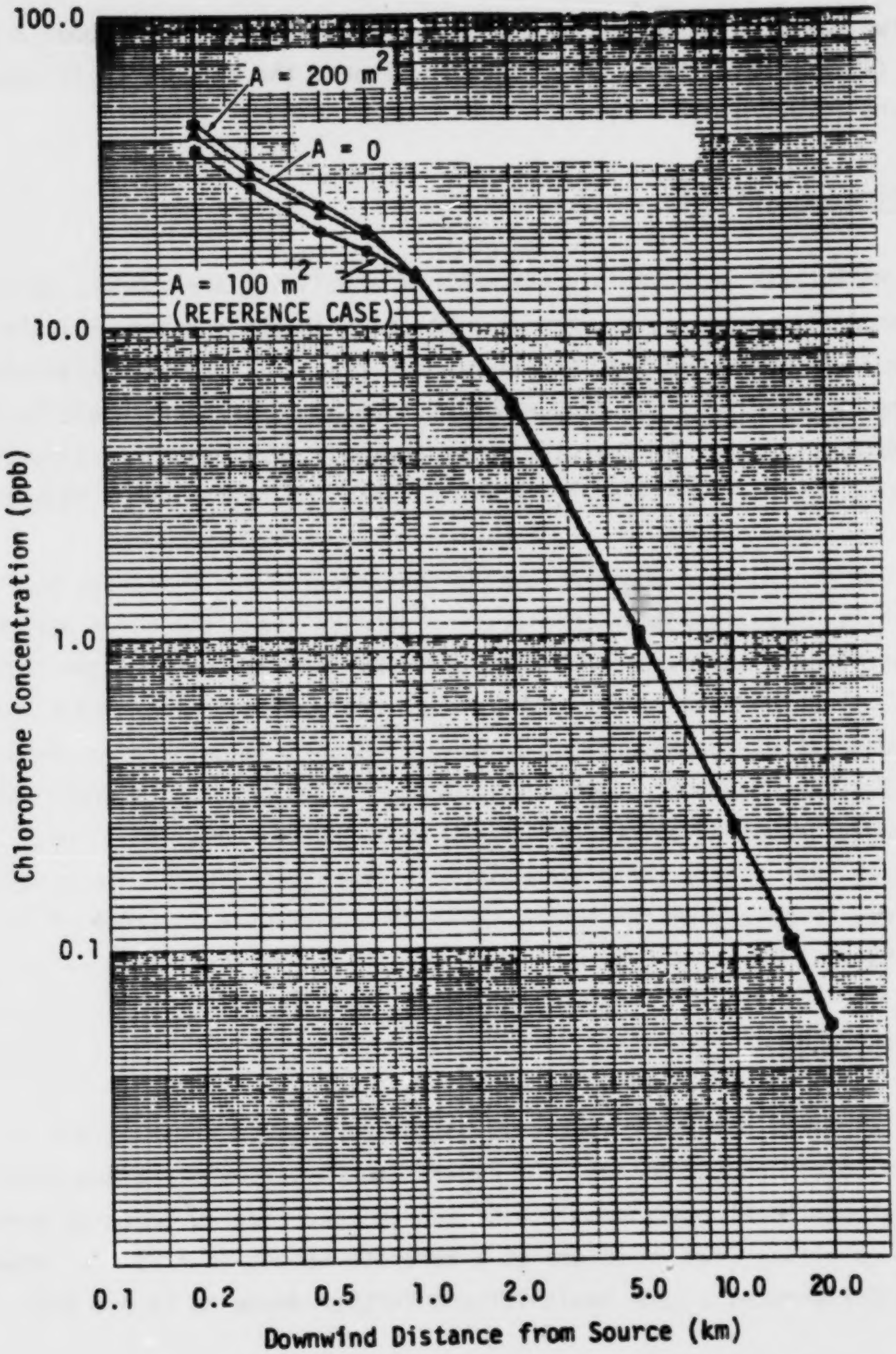
Building Wake Effect

Pollutants emitted into the wake of a building are subject to an enhanced dispersion (i.e., the concentration is reduced very quickly by the turbulence on the lee side of the building). If a dispersion analysis ignored this effect, the occurrence of high concentrations would be overestimated. A detailed description of the equations used in estimating the building wake effect is addressed in the section beginning on page 121.

The ground-level concentrations that result from different building structure dimensions are depicted in Figure 8, where the major parameters for estimating these concentrations are the same as those of the reference case. Clearly, the building wake effect would have insignificant impacts on ground-level concentrations at points further downwind from the source than 1.0 km. However, sources with larger building effects would result in larger ground-level concentrations near the sources. Additional analyses that assess the precise impacts of building wake effect may be required to determine the extent to which the example in Figure 8 is site-specific.

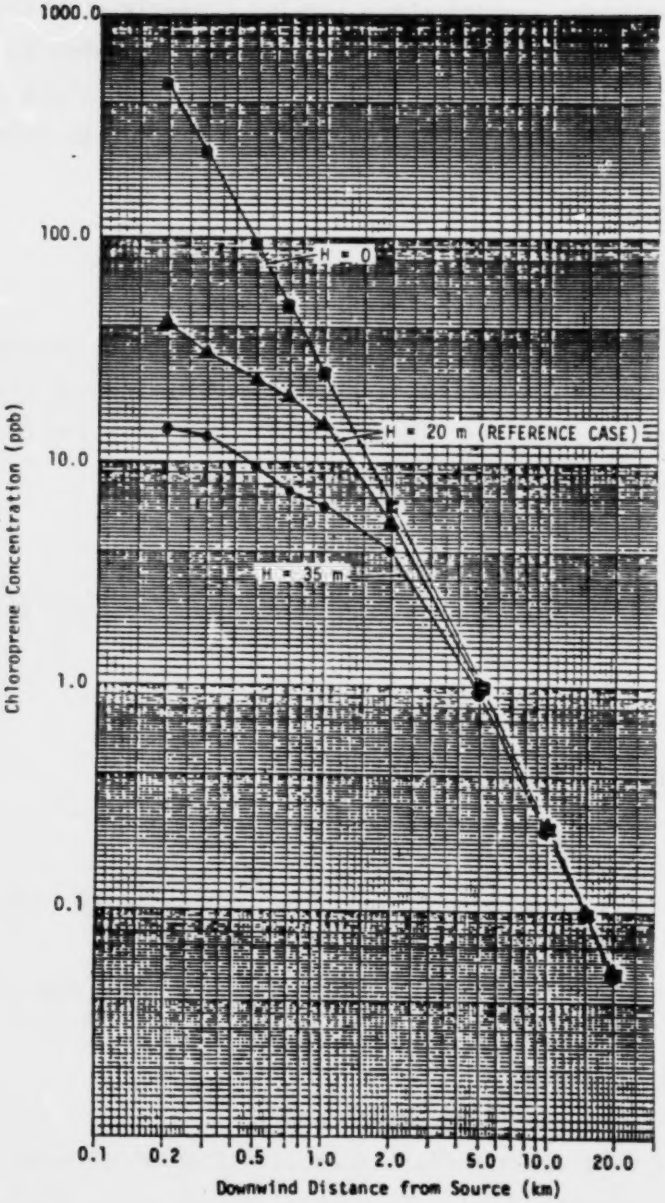
Release Height

The exact release height of a source can have a great effect on ground-level concentrations. As Figure 9 shows, concentrations resulting from ground-level emissions ($H = 0$) can be more than 10 times as great as those resulting from emissions at a moderate height ($H > 20$ m). However, these differences become insignificant further downwind ($R > 5$ km).



Source: Systems Applications, Incorporated computations using SAI dispersion model and SAI building wake algorithms.

FIGURE 8. EFFECT OF BUILDING WAKE ON CONCENTRATION DISTRIBUTION OF CHLOROPRENE



Source: Systems Applications, Incorporated computations using SAI dispersion model and Briggs' plume rise formulas

FIGURE 9. IMPACTS OF RELEASE HEIGHT ON CONCENTRATION DISTRIBUTION OF CHLOROPRENE

The evidence from Figures 7, 8, and 9 indicates that ground-level concentrations decrease approximately log-log linearly with distance at receptors more than 2 km distant from the source. Apparently, a plot of this log-log linear relationship could be used to interpolate concentrations at specific locations within the range of 2 to 20 km from the source.

The Point Source Algorithm

The annual average concentration pattern of a given chemical compound downwind from an emissions source is estimated by using the climatological form of the Gaussian algorithm (Turner, 1970) that is given by the detailed equation used to prepare the computer program:

$$\chi(R,\theta,H,\tau_k) = 2.03Q \sum_i \sum_j \frac{\mathrm{STAR}(\theta,S_j,N_i)\,\mathrm{EXP}(R,S_j,H)}{U(N_i)\;R\sigma_z(R,S_j)} \cdot \mathrm{DEC}(R,S_j,N_i,\tau_k) \tag{4}$$

where the symbols have the following meanings:

Polar Coordinates

R = Distance (meters) from the source to the receptor,

θ = Compass azimuth of the radius, R; also wind azimuth.

Atmospheric Parameters

u = wind speed (meters/second),

θ = wind azimuth (i.e. direction from which wind is blowing),

σ_z = vertical dispersion coefficient $\left(\frac{\text{meter}}{\text{second}}\right)^2$,

N_i = the i-th wind speed category,

S_k = the k-th dispersion (stability) category.

Functions

STAR = The STability ARray* of joint probabilities of occurrence of wind speed, direction and stability combinations,

EXP = Gaussian dispersion function for elevated pollutant plume.

DEC = Decay function characterizing loss of chemical species, k, due to atmospheric chemical reactions.

Emission Parameters

Q = Emissions rate (grams/second),

H = Effective plume height (meters).

Species Parameter

τ_k = Decay rate of species k due to atmospheric chemical reaction.

Grid System

A polar grid array of sectors of uniformly increasing size radially outward from the source was used to overlay the region of interest. Concentration is calculated at the four corners of each sector. Another use of the grid system is to catalog population data for exposure/dosage calculations.

Climatological Parameters

The STAR data were obtained from the National Climatic Center (Asheville, North Carolina). As received they were not in a uniform format with respect to the stability used. Data from some stations was in the original STAR format with up to eight stability classes. Data from other stations had been modified so as to distinguish between day and nighttime occurrences of neutral D stability. After receipt from the NCC, all unmodified data sets were modified according to the present EPA day-night system (Busse and Zimmerman, 1973), as shown in Table 14. This splitting of the neutral stability data is especially important when other processes, such as chemical reactions, have diurnal variations.

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* Site-specific, from data from several hundred sites in U.S.

For all the point source analyses, neutral (D) stability events designated by the regular STAR data are divided into two classes: 40 percent of the neutrally stable hours are assumed to occur at night, and the remaining 60 percent in the daytime (Burt, 1977).

Since the lower portion of the atmosphere over urban areas is usually unstable, even when the adjacent rural area is stable, neutral stability is assumed for point sources analyses in urban areas whenever the STAR algorithm indicates stable conditions (Classes E and F). This procedure follows the recommendations of the EPA.

TABLE 14. PASQUILL-GIFFORD STABILITY CLASSES USED IN POINT SOURCE ANALYSES

Pasquill/Gifford Stability Classes	Urban Areas	Rural Areas
A	A	A
B	B	B
C	C	C
D	D-day	D-day
E	D-night	D-night
E	D-night	E
F	D-night	F

Source: Busse and Zimmerman (1973).

Wind Speed

The wind speed $U(N_i)$ for each wind speed class is taken as the average wind speed of the range for the given class (Busse and Zimmerman, 1973).

Vertical Variation of Wind Speed

Generally, the wind speed at plume height will differ from the measured wind speed at the anemometer height of 10 meters. To account for this vertical variation, a power law wind profile in the form

$$U(H) = U_{10}\left(\frac{H}{10}\right)^{P} \qquad (5)$$

was used, as recommended by Turner (1970). The exponent p, as presented in EPA (1977), is listed for each stability class:

Pasquill/Gifford Stability Classes	P
A	0.10
B	0.15
C	0.20
D	0.25
E	0.30
F	0.30

Plume Height

The height of the plume centerline, he, is the sum of the physical stack height, hs, and the plume rise, Δh:

$$he = hs + \Delta h \quad . \tag{6}$$

In this analysis, plume rise is determined using Briggs's equations (1969, 1970, 1975) for momentum plumes and buoyancy plumes from low level emissions sources as recommended by Turner and Novak (1978).

Vertical Dispersion Function

The value of σ_z where emissions do not suffer from downwash phenomena is calculated from formulas recommended by Briggs (1973), where R is the downwind distance in meters:

Pasquill Stability Class	σ_z (m)
A	$0.20\ R$
B	$0.12\ R$
C	$0.08\ R\ (1. + 0.0002\ R)^{-1/2}$
D(day and night)	$0.06\ R\ (1. + 0.0015\ R)^{-1/2}$
E	$0.03\ R\ (1. + 0.0003\ R)^{-1}$
F	$0.16\ R\ (1. + 0.0003\ R)^{-1}$

The proposed formulas for σ_z for emissions that are influenced by building wakes are:

Pasquill Stability Class	σ_z (m)
A	$0.20\ (R + \Delta R)$
B	$0.12\ (R + \Delta R)$
C	$0.08\ (R + \Delta R)[1. + 0.0002\ (R + \Delta R)]^{-1/2}$
D	$0.06\ (R + \Delta R)[1. + 0.0015\ (R + \Delta R)]^{-1/2}$
E	$0.03\ (R + \Delta R)[1.0.0003\ (R + \Delta R)]^{-1}$
F	$0.16\ (R + \Delta R)[1. + 0.0003\ (R + \Delta R)]^{-1}$

where ΔR is the displacement distance and is calculated using:

Pasquill Stability Class	ΔR (m)
A	$1.95\ A^{0.5}$
B	$2.72\ A^{0.5}$
C	$4.09\ A^{0.5}$
D	$4.95\ A^{0.5}$
E	$9.03\ A^{0.52}$
F	$14.88\ A^{0.52}$

Chemical Decay

The four-class scheme for photochemical decay categorization is adopted in the dispersion models. The default values of reaction rate constants for each class are listed below:

Time of Day	Class I Very Reactive	Class II Reactive	Class III Moderately Reactive	Class IV Unreactive
Daytime	1.0×10^{-2}	5.0×10^{-3}	5.0×10^{-4}	0
Nighttime	5.0×10^{-5}	5.0×10^{-5}	0	0

Source: Systems Applications, Incorporated, review as described in Section 2, pp. 66 ff.

Matrix Modeling Technique

To save computing time, the Gaussian algorithm $[2.03\ \mathrm{EXP}(R,S_j,H)/\delta_z(R,S_j)]$ and the decay function $(\exp\,[-\psi_K(S_j)R/U(N_i)])$ from Eq. (4) are used to generate files of normalized Gaussian solutions--one for each combination of six wind speed categories, seven stability classes, and four chemical reactivity groups. For each of the combinations, 10 different downwind distances R, 16 wind directions θ, and 5 different effective stack heights are used. The values chosen for the 10 different downwind distances are 0.2, 0.3, 0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 15.0, and 20.0 kilometers. The values for the wind speeds are 1.50, 2.46, 4.47, 6.93, 9.61, and 12.52 m/sec. The values chosen for the effective stack height are 0.0, 5.0, 10.5, 20.0, and 35.0 meters.

Sector Averaging

The constant 2.03 of Eq. (4) is the product of the factors $2/(\sqrt{2\pi}\ 2\pi/16)$. This is obtained from the bivariate Gaussian sector averaging form for a 22.5° (i.e., $2\pi/16$) sector. This results in a uniform concentration across the wind sector at a given distance and height.

Operation

MATRIX and GAUSS are the two major computer programs used in major point source analysis. The function of program MATRIX is to generate a matrix file containing dispersion functions as a function of wind direction and radial distance from the source for a single point source with a chosen physical characteristic. The GAUSS program reads the matrix data file generated by MATRIX and calculates the ground concentration pattern carried by the sources defined in the source definition data set. Output from GAUSS is a data file that contains surface concentration values.

There is no input data requirement to run the MATRIX program. However, GAUSS does require input. In addition to the intermediate data file created by MATRIX, GAUSS requires an input data set that identifies the locations and characteristics of the sources as well as the surrounding meteorological and climatological conditions. Sequences of input data cards are shown in Table 15.

Vertical Dispersion Function for Downwash Phenomena

When the pollutants are emitted from a vent or opening on a building, or when the exit velocity of gases emitted from a stack is less than 1.5 times the mean wind speed, dispersion of pollutants is determined by the atmospheric dispersion mechanism and the building-induced turbulence.

Following Briggs (1975), the atmospheric dispersion function for $\sigma_y(x)$, m, and $\sigma_z(x)$ can be expressed as follows (open country conditions, $10^2 < x < 10^4$m):

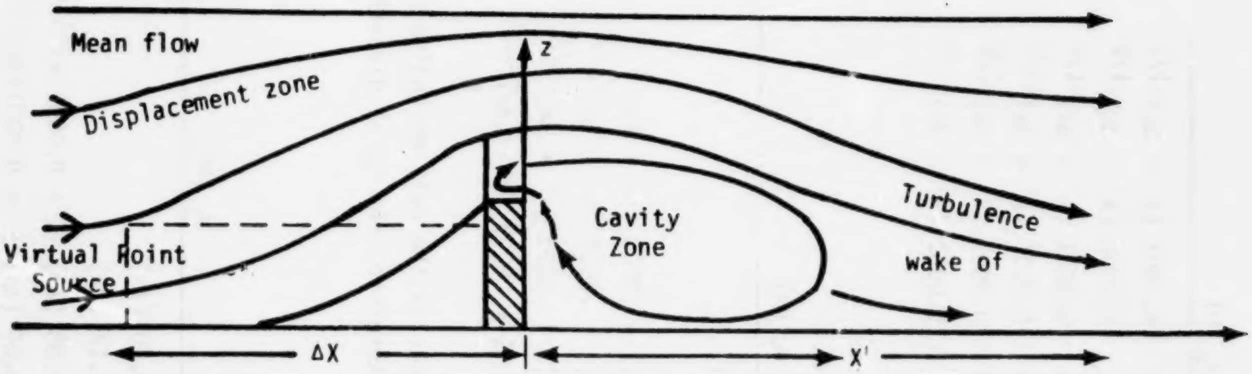
Pasquill Type	σ_y(m)	σ_z(m)
A	$.22x(1 + .001x)^{-1/2}$	$.20x$
B	$.16x(1 + .0001x)^{-1/2}$	$.12x$
C	$.11x(1 + .0001x)^{-1/2}$	$.08x(1 + .0002x)^{-1/2}$
D	$.08x(1 + .0001x)^{-1/2}$	$.06x(1 + .0015x)^{-1/2}$
E	$.06x(1 + .0001x)^{-1/2}$	$.03x(1 + .0003x)^{-1}$
F	$.04x(1 + .0001x)^{-1/2}$	$.016x(1 + .0003x)^{-1}$

Estimation of the additional initial dispersion in the building wake is based on Holland's virtual point source concept. In this concept, dispersion is as if the emissions came from a virtual source, farther upwind than the real one and diffused by Gaussian processes to a plume as wide as the building wake. The downwind distance x can be expressed as $x' + \underline{\Delta x}$, where x' is the distance between the receptor and the actual emission source, while $\underline{\Delta x}$ is the distance between the actual point source and virtual point source (see Figure 10). The total dispersion factor can be expressed as:

TABLE 15. SEQUENCE OF INPUT DATA CARDS FOR PROGRAM GAUSS

Card No.	Variables	Format	Contents
1	NEMS	I10	Number of emissions sources
2	LINE	7A5	Emissions source identifier
	LAT	I6	Latitude (degree, minute, second)
	LONG	I7	Longitude (degree, minute, second)
	ISTAR	I5	Chosen STAR station number
	T	F5.0	Ambient temperature (°K)
	ALAPSE	2F5.0	Lapse rate for stability class E, F
	IURB	I1	Urban index IURB = 1 for rural area IURB = 0 for urban area
3	IUSE	I5	User identifier
	NOS	I2	Number of source type within each emissions source
	ISPEC	A10	Name of the chemical
	ICSPEC	A10	Compounds
4	IEMTYP	ZX,A1	Emissions index
	Q	F12.0	Emissions rates (lbs/hr)
	STAK	F4.0	Physical stack height (meters above ground level)
	XA	F4.0	Typical building cross sectional area (meters^2)
	IVENT	I1	Stack index IVGNT = 1 for nonvertical stack IVGNT = 0 for vertical stack
	D	F4.0	Stack diameter (meters)
	VS	F5.0	Gas exit velocity (m/s)
	TS	F4.0	Gas exit temperature (°K)

Note: GAUSS also requires the SAI-modified STAR data file.


Mean flow
Displacement zone
Virtual Point Source
z
Cavity Zone
Turbulence
wake of
ΔX
X'

Q = Emission source strength

ΔX = Distance between the virtual point source and the actual point source as a result of the building of displacement zone

FIGURE 10. SCHEMATIC ILLUSTRATION OF VIRTUAL POINT SOURCE CONCEPT

Pasquill Type	σ_y (m)
A	$.22\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
B	$.16\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
C	$.11\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
D	$.08\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
E	$.06\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
F	$.04\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$

Pasquill Type	σ_z (m)	
A	$0.20\ (x' + \Delta x)$	(6a)
B	$0.12\ (x' + \Delta x)$	(6b)
C	$0.08\ (x' + \Delta x)\ (1 + .0002\ (x' + \Delta x)^{-1/2}$	(6c)
D	$0.06\ (x' + \Delta x)\ (1 + .0015\ (x' + \Delta x)^{-1/2}$	(6d)
E	$0.03\ (x' + \Delta x)\ (1 + .0003\ (x' + \Delta x)^{-1/2}$	(6e)
F	$0.016\ (x' + \Delta x)\ (1 + .0003\ (x' + \Delta x)^{-1/2}$	(6f)

For x'=o, the building-induced turbulence is the only mechanism that controls the dispersion of pollutants. Therefore, the total dispersion function here can be expressed as:

σ_y (m)	σ_z (m)	
$.22\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.20\ (\Delta x)$	(7a)
$.16\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.12\ (\Delta x)$	(7b)
$.11\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.08\ (\Delta x)\ (1 + 0.0002\Delta x)^{-1/2}$	(7c)
$.08\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.06\ (\Delta x)\ (1 + 0.00015\Delta x)^{-1/2}$	(7d)
$.06\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.03\ (\Delta x)\ (1 + .0003\Delta x)^{-1}$	(7e)
$.04\ (\Delta x)\ (1 + 0.0001Wx)^{-1/2}$	$0.016\ (\Delta x)\ (1 + .0003\Delta x)^{-1}$	(7f)

The product of σ_y and σ_z is:

$$\sigma_y \ \sigma_z \ (m^2) =$$

$$4.4 \times 10^{-2} \ (\Delta x)^2 \ [1 + 10^{-4} \ (\Delta x)]^{-1/2} \tag{8a}$$

$$1.9 \times 10^{-2} \ (\Delta x)^2 \ [1 + 10^{-4} \ (\Delta x)]^{-1/2} \tag{8b}$$

$$8.8 \times 10^{-3} \ (\Delta x)^2 \ [1 + 3. \times 10^{-4} \ (\Delta x) + 2 \times 10^{-8} \ (\Delta x)^2 \ ]^{-1/2} \tag{8c}$$

$$4.8 \times 10^{-3} \ (\Delta x)^2 \ [1 + 1.6 \times 1^{-3} \ (\Delta x) + 1.5 \times 10^{-7} \ (\Delta x)^2]^{-1/2} \tag{8d}$$

$$\begin{aligned} 1.8 \times 10^{-3} \ (\Delta x)^2 \ \ 1 + 7.0 \times 10^{-4} \ (\Delta x) + 1.5 \times 10^{-7} \ (\Delta x)^2 \\ + 9. \times 10^{-12} \ (\Delta x)^2 \ {-1/2} \end{aligned} \tag{8e}$$

$$\begin{aligned} 6.4 \times 10^{-4} \ (\Delta x)^2 \ \ 1 + 7.0 \times 10^{-4} \ (\Delta x) + 1.5 \times 10^{-7} \ (\Delta x)^2 \\ + 9. \times 10^{-12} \ (\Delta x)^2 \ {-1/2} \end{aligned} \tag{8f}$$

Gifford (1968) identified the total diffusion factor as:

$$\sigma_y = (\sigma_y{}^2 + CA/\pi)^{1/2} \quad ,$$

where A is building cross sectional area perpendicular to the mean wind and C is the building factor.* It is found that $0.5 < C < 2.0$. At $X'=0$, the total dispersion function becomes

$$\sigma_y = (CA/\pi)^{1/2} \quad ,$$

$$\sigma_z = (CA/\pi)^{1/2} \quad ,$$

Multiply σ_y and σ_z to obtain:

---

* Dependence on the height/width ratio of a building was not included. There is great variety in the sizes and shapes of buildings associated with the variety of emissions sources. Generally, the structures were complex, there was uncertainty as to how well this correction should be detailed, and it was difficult to obtain relevant data.

$$\sigma_y \sigma_z = CA/\pi \quad . \qquad (9)$$

Let C = 0.5 (a conservative estimation), and compare Eqs. (8a), (8b), (8c), (8d), (8e), and (8f) with Eq. (9); one gets:

Pasquill Stability	$\sigma_y \; \sigma_z \; (m^2) = \frac{CA}{\pi}$	
A	$4.4 \times 10^{-2} (\Delta x)^2 [1 + 10^{-4} (\Delta x)]^{-1/2}$	(10a)
B	$1.9 \times 10^{-2} (\Delta x)^2 [1 + 10^{-4} (\Delta x)]^{-1/2}$	(10b)
C	$8.8 \times 10^{-3} (\Delta x)^2 [1 + 3. \times 10^{-4} (\Delta x)$	
	$+ 2 \times 10^{-8} (\Delta x)^2]^{-1/2}$	(10c)
D	$4.8 \times 10^{-3} (\Delta x)^2 [1 + 1.6 \times 1^{-3} (\Delta x)$	
	$+ 1.5 \times 10^{-7} (\Delta x)^2]^{-1/2}$	(10d)
E	$1.8 \times 10^{-3} (\Delta x)^2 \;\; 1 + 7.0 \times 10^{-4} (\Delta x) + 1.5 \times 10^{-7} (\Delta x)$	
	$+ 9. \times 10^{-12} (\Delta x)^2 \; {-1/2}$	(10e)
F	$6.4 \times 10^{-4} (\Delta x)^2 \;\; 1 + 7.0 \times 10^{-4} (\Delta x) + 1.5 \times 10^{-7} (\Delta x)^2$	
	$+ 9. \times 10^{-12} (\Delta x)^2 \; {-1/2}$	(10f)

Eqs. (10a) through (10f) are then solved numerically, and the Δx can be expressed as:

Pasquill Stability	Δx
A	$1.95A^{0.5}$
B	$2.72A^{0.5}$
C	$4.05A^{0.5}$
D	$4.95A^{0.5}e^{A} \times 10^{-6}$
E	$9.03A^{0.52}e^{3.6A} \times 10^{-6}$
F	$14.88A^{0.52}e^{A} \times 10^{-5}$

By substituting them into Eqs. (6a) through (6f), one can obtain the total dispersion function.

Exposure and Dosage Estimation Scheme

SAI has coded this "matrix" dispersion modeling approach into a standard Fortran program. The output of the program is a well-formatted concentration array for 160 receptors around the plant (10 receptors along each of the 16 wind directions). These are the sum of concentration patterns resulting from all sources within a plant. A typical concentration pattern printout is shown in Table 16, and the chloroprene-emitting Denka plant at Houston is used here as an example. This subsection delineates the basic approach used in combining the concentration pattern with the population distribution pattern around a plant. Two terms are defined here and are used frequently in the following discussion. A polar grid point is one of the 160 receptors at which concentrations were estimated by the dispersion modeling. A population centroid is the population-weighted geographical center of an ED/BG for which geodetic coordinates are known.

A two-level scheme was adopted to pair up concentrations and populations prior to the computation of dosages and exposures. The two-level approach is appropriate because the concentrations are defined on a radius-azimuth (polar) grid pattern with non-uniform spacing. At small radii the grid cells are much smaller than ED/BGs; at large radii the grid cells are much larger than ED/BGs. To form the product of population times concentration, both factors at the same set of points are required. Interpolation techniques to accomplish this are most appropriately applied by interpolating values of the factor defined on the coarse network at the locations of the finer grid, thus maximizing the resolution and minimizing the uncertainties of interpolation. Because the fine/coarse relationship varies with radius, the two-level approach is used.

For ED/BG centroids located between 0.1 km and 2.8 km from the source, populations were apportioned among neighboring concentration grid

TABLE 16. ANNUAL AVERAGE CHLOROPRENE CONCENTRATION DISTRIBUTION PATTERN IN THE VICINITY OF THE DENKA PALNT IN HOUSTON, TEXAS

Chloroprene Concentration (g/m**3)

Wind direction	Downwind Distance (m)									
	200.00	300.00	500.00	700.00	1000.00	2000.00	5000.00	10000.00	15000.00	20000.00
1	.14942E-04	.95580E-05	.50743E-05	.32616E-05	.19506E-05	.60156E-06	.10097E-06	.24494E-07	.10522E-07	.57312E-08
2	.10168E-04	.65569E-05	.35085E-05	.22476E-05	.13352E-05	.40851E-06	.68605E-07	.16717E-07	.72068E-08	.39377E-08
3	.13662E-04	.89314E-05	.49199E-05	.32591E-05	.20031E-05	.63664E-06	.10886E-06	.26667E-07	.11501E-07	.62744E-08
4	.93610E-05	.61220E-05	.33440E-05	.21873E-05	.13271E-05	.41623E-06	.70896E-07	.17372E-07	.74953E-08	.40910E-08
5	.17444E-04	.11260E-04	.60669E-05	.39771E-05	.24292E-05	.76792E-06	.13050E-06	.31737E-07	.13612E-07	.73934E-08
6	.21159E-04	.13642E-04	.73193E-05	.47477E-05	.28649E-05	.89354E-06	.15131E-06	.36901E-07	.15895E-07	.06747E-08
7	.25284E-04	.16369E-04	.88764E-05	.58142E-05	.35399E-05	.11146E-05	.18966E-06	.46349E-07	.19983E-07	.19212E-07
8	.17728E-04	.11470E-04	.62141E-05	.40536E-05	.24554E-05	.76858E-06	.13057E-06	.31950E-07	.13802E-07	.75536E-08
9	.28801E-04	.18481E-04	.99365E-05	.65771E-05	.40685E-05	.13053E-05	.22338E-06	.54546E-07	.23487E-07	.12811E-07
10	.11375E-04	.73260E-05	.39629E-05	.26502E-05	.16575E-05	.53827E-06	.92638E-07	.22657E-07	.97544E-08	.53156E-08
11	.10625E-04	.69450E-05	.38875E-05	.27226E-05	.17797E-05	.60395E-06	.10570E-06	.25916E-07	.11130E-07	.60376E-08
12	.47475E-05	.30813E-05	.17087E-05	.11998E-05	.78846E-06	.26901E-06	.47015E-07	.11474E-07	.49088E-08	.26537E-08
13	.55382E-05	.35492E-05	.19359E-05	.13315E-05	.85815E-06	.28704E-06	.49716E-07	.12118E-07	.51918E-08	.28131E-08
14	.51789E-05	.33139E-05	.17869E-05	.11999E-05	.75437E-06	.24602E-06	.42199E-07	.10266E-07	.44002E-08	.28871E-08
15	.74764E-05	.48679E-05	.26834E-05	.18047E-05	.11298E-05	.36659E-06	.63154E-07	.15486E-07	.66779E-08	.36417E-08
16	.49227E-05	.31853E-05	.17161E-05	.11088E-05	.66469E-06	.20559E-06	.34766E-07	.85183E-08	.36872E-08	.20211E-08

Source: Systems Applications, Incorporated.

points. There are 96 (6 x 16) polar grid points within this range. Associated with each of these grid points, at which the concentration is known, is a smaller polar sector bounded by two concentric arcs and two radial lines. The boundary concentric arcs were defined by radii of 0.1, 0.25, 0.4, 0.6, 0.8, 1.2, and 2.8 km in this study, and the boundary radial lines were drawn right in the middle of two wind directions. Each of these concentration grid points was assigned to the nearest ED/BG centroid identified from the MED-X data set. The population at each centroid was then apportioned among all concentration grid points assigned to that centroid. The exact land area within each polar cell was considered in the apportionment, and the population density was assumed to be the same for all grid cells assigned to a single centroid. Both concentration and population counts were thus available for each polar grid point.

Log-log linear interpolation was used to estimate the concentration at each ED/BG population centroid located between 2.8 km and 20 km from the source. Concentration estimates for 80 (5 x 16) grid points (receptors at 2.0, 5.0, 10.0, 15.0, and 20.0 km from the source along each of the sixteen directions) resulting from dispersion modeling were used here as reference points for this interpolation. For each ED/BG centroid, four reference points were located as the four corners of the polar sector in which the centroid is located. These four reference points would surround the centroid as depicted in Figure 11. As shown in Figures 7, 8, and 9, there is a linear relationship between the logarithm of concentrations and the logarithm of distances for receptors more than 2 km away from the source. This relationship was used to estimate the concentrations at points E and F (see Figure 11). These estimates, together with the polar angles, were then used to interpolate the concentration at the centroid. Using the two-level approach, concentrations and populations wre paired up for the 96 concentration grid points within 2.8 km of the source and for all ED/BG centroids located between 2.8 km and 20 km from the source. The total dosage was then computed as follows:

$$\text{Total Annual Dosage } (\mu g/m^3\text{-person}) = \sum_{i=1}^{N} P_i C_i \quad ,$$

where P_i = the population at point i, C_i = the annual average concentration at point i, and N = the total number of grid points and ED/BG centroids with a specified combination of concentration and population (representing the entire area within 20 km of the source).

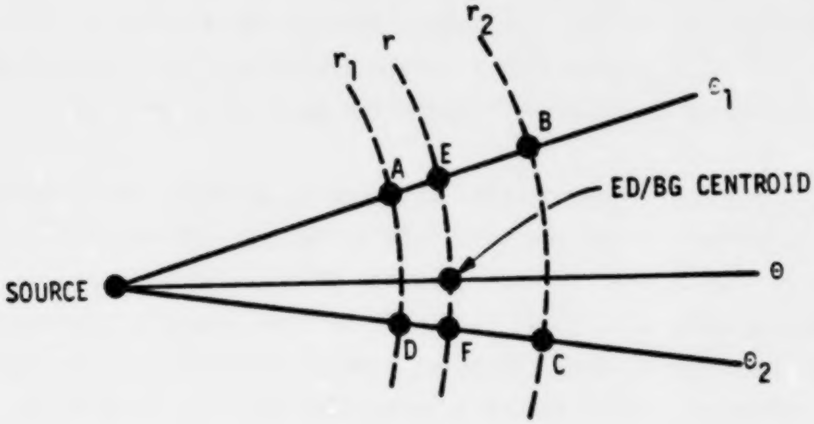


FIGURE 11. REFERENCE POINTS FOR AN ED/BG CENTROID

The population exposed to each of a number of concentration levels, L_j, was computed by:

$$\text{Exposure to } L_j \text{ (person)} = \sum_{i=1}^{N} P_i S_i(C_i, L_j) \quad ,$$

where

$$S_i = \begin{cases} 0 \quad , & \text{if } C_i < L_j \\ 1 \quad , & \text{if } C_i \geq L_j \end{cases} \quad .$$

The dosage of the fraction of the population that is exposed to concentrations greater than or equal to each of a number of concentration levels, L_j, was computed by using the following summation:

$$\text{Annual Dosage at } L_j \ (\mu g/m^3\text{-person}) = \sum_{i=1}^{N} P_i C_i S_i (C_i, L_j) \quad .$$

Note that the annual dosage at the minimum concentration within 20 km of the source will equal the total annual dosage.

The concentration levels at which exposure is to be estimated can be selected either manually or by an exponential function coded in the program. A suggested approach is to select the desired number of concentration levels, examine the exposure computed at the program-determined exposure levels, and then compute the exposures at selected levels.

The version of the MED-X data file used in these estimations includes the 1970 census data, so both exposure and dosage have to be adjusted to the 1978 levels. The 1978 to 1970 population ratio at the county level was used as the adjustment factor in this study. The exposure algorithm program was used to estimate the exposure/dosage for each of the major point sources and total nationwide exposure/dosage.

PROTOTYPE POINT SOURCE EXPOSURE AND DOSAGE ESTIMATION APPROACH

Significant amounts of chemicals are emitted from point sources that, practically, can only be treated generically. Such sources may include power plants, refineries, solvent degreasers, solvent users, gas stations, etc.; they are too numerous to be treated individually as point sources, and yet the spatial distributions of their emissions are not sufficiently uniform to be treated as area source emissions.

SAI conducted a study to compare two approaches for estimating the exposure-dosage resulting from chemical emissions from point sources treated as classes. The first approach assumes that these sources are area sources and that the Hanna-Gifford Model can be used to estimate atmospheric concentrations. This approach was applied to estimate the benzene concentration/dosage resulting from gasoline station emissions in an EPA report on human exposure to atmospheric benzene (Mara and Lee, 1978). In the alternative approach, model or prototype sources were defined; exposure estimates for each model source were developed in the same fashion as they were for major, specifically identified point sources. The results were then multiplied by the estimated number of sources of the same type to obtain national totals.

Trichloroethylene emitted from metal degreasing facilities is used as an example in this comparison study. Trichloroethylene has been the historical favorite for vapor degreasing uses, but regulations have been instituted regarding its use for metal cleaning because of its toxicity, its photochemical reactivity, and the resultant formation of undesirable byproducts. Vapor degreasers (VD) lose a relatively smaller portion of their solvents in waste material and as liquid carryout than do cold degreasers (CD). For both VDs and CDs, most (> 99 percent) of the emissions are those vapors that diffuse from the degreasers. Trichloroethylene vapor degreasing emissions are estimated by HI to have been 104,550 metric tons in 1978, or 99 percent of the total amount of trichloroethylene consumed for this purpose (see Attachment A). An estimated 15 percent of trichloroethylene consumed in metal degreasing operations was used in cold cleaning equipment. The remaining 85 percent was used in open top vapor degreasers (OTVDs) and conveyorized vapor degreasers (CVDs). The averaging emissions rates per unit and the total number of units in operation nationwide are shown in Table 17.

TABLE 17. NATIONWIDE TRICHLOROETHYLENE EMISSIONS FROM SOLVENT DEGREASERS

Type of Degreaser	National Emissions (metric tons/yr)	Number of Degreasers	Average Emissions Rate per Degreaser (g/sec)
Cold degreaser	14,950	49,770	0.0095
Open top vapor degreaser	55,570	6,110	0.288
Conveyorized vapor degreaser	33,340	1,232	0.858
Total	104,550	59,382	--

Source: Hydroscience, Incorporated, Knoxville, Tennessee, trichloroethylene emissions summary; included in attached species report.

In this study, model sources were defined for each of the nine geographic regions in the United States. Figure 12 displays the nine regions. The average emissions rate per degreaser, as listed in Table 17, is assumed applicable to all nine regions, and the deviations from the average rates are regarded as insignificant in terms of their influence on the overall exposure-dosage estimates. Therefore, there are three types of model sources in each region for trichloroethylene, and their emissions rates were assumed to be the average rates as listed in Table 17. However, for some model sources of other chemicals, the emissions rates may be different from region to region.

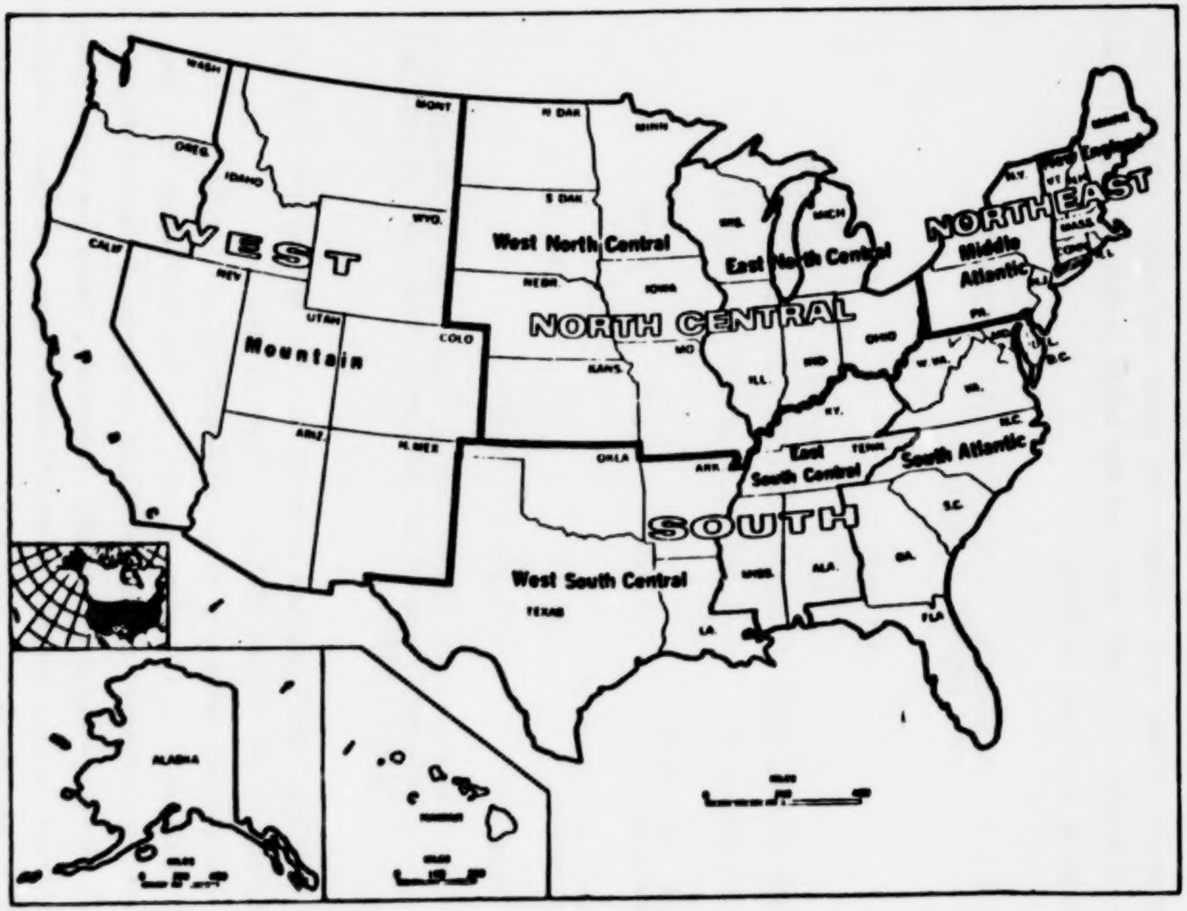

WEST
Mountain
NORTH CENTRAL
West North Central
East North Central
NORTHEAST
New England
Middle Atlantic
SOUTH
South Atlantic
East South Central
West South Central
WASH
OREG
CALIF
IDAHO
NEV
MONT
WYO
UTAH
COLO
ARIZ
N. MEX
N DAK
S DAK
NEBR
KANS
MINN
IOWA
MO
WIS
MICH
ILL
IND
OHIO
N.Y.
PA
N.J.
MAINE
VT
MASS
CONN
DEL
MD
D.C.
W. VA
VA
N.C.
S.C.
KY
TENN
GA
FLA
ALA
MISS
ARK
LA
OKLA
TEXAS
ALASKA
HAWAII
MILES

FIGURE 12. U.S. GEOGRAPHIC REGIONS

Degreasers that use trichloroethylene as a solvent are usually employed in the manufacturing industry; the population exposed to emissions from this type of source resides mostly in urbanized areas. In this study, all trichloroethylene-using degreasers were assumed to be located in urbanized areas with populations of more than 25,000. These urbanized areas were also the major exposed areas. An attempt was made to estimate the total land area in each region, and the average population density in these urbanized areas for each region was also derived. Table 18 lists these statistics together with the number of each of the three types of degreasers in each of the nine regions. The 1978 population density in these urbanized areas was assumed not to differ significantly from the 1972 figure. The population and land area data were from the 1970 census data (U.S. Bureau of the Census, 1973) and data on the number of degreasers were estimates made by HI.

Uniform Emissions Approach

In this approach, trichloroethylene was assumed to be emitted uniformly throughout the area covered. To calculate the average annual area-wide trichloroethylene concentrations, χ, resulting from vapor degreasing emissions, the Hanna-Gifford dispersion equation was used:

$$\chi = \frac{225\ Q}{u} \quad , \qquad (16)$$

where

Q = average emissions rate of trichloroethylene from unit area ($\mu g/sec - m^2$),
u = average wind speed (m/sec),
225 = an empirical factor derived from several previous studies on relatively large scale urban areas ($\sim 400\ km^2$) and under neutral atmospheric stability.

TABLE 18. 1970 POPULATION DENSITY AND NUMBER OF TRICHLOROETHYLENE-USING DEGREASERS IN THE NINE GEOGRAPHIC REGIONS

Region Code	Region	Statistics in Urbanized Areas[*] Population (in thousands)	Area (km^2)	Density (persons/km^2)	Number of Degreasers[†] CD[§]	OTVD[**]	CVD[††]
1	New England	8,098	7,650	1,059	2,991	560	113
2	Middle Atlantic	27,959	14,084	1,985	7,760	1,158	244
3	East North Central	26,506	19,543	1,356	13,179	1,742	405
4	West North Central	8,450	8,402	1,006	4,362	452	80
5	South Atlantic	15,862	14,102	1,125	6,005	465	84
6	East South Central	4,173	4,986	837	2,944	265	52
7	West South Central	10,948	12,312	889	4,832	398	68
8	Mountain	4,692	4,772	983	1,806	174	21
9	Pacific	20,582	14,335	1,436	5,893	896	165

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[*] Source: U.S. Bureau of Census, 1973.

[†] Source: Hydroscience, Incorporated, Knoxville, Tennessee, trichloroethylene emissions summary included in Attachment A.

[§] Cold Degreaser.

[**] Open Top Vapor Degreaser.

[††] Conveyorized Vapor Degreaser.

Since this approach does not consider concentration patterns, patterns of wind variability were not judged to be pertinent, and a mean, national average wind was used. The average U.S. wind speed was determined to be 5.5 m/sec by weighting regional average wind speeds by population, (Mara and Lee, 1978). Because it was assumed that all of the vapor degreasers are located in Urbanized Areas, the total land area of the Urbanized Areas in the United States (U.S. Bureau of the Census, 1973) was used in the estimation of unit area emissions rates (Q). Table 19 lists the major parameters used in this approach, together with the estimated concentration-dosage results. It should be noted that no information on the differentiation of levels of exposure to the populations residing in the Urbanized Areas is available, and only the average exposed concentration is derived from this approach.

TABLE 19. MAJOR PARAMETERS AND CONCENTRATION-DOSAGE RESULTS OF THE UNIFORM EMISSIONS APPROACH

Major Parameters	Concentration-Dosage Results	Information Source
Total trichloroethylene vapor degreasing emissions	104,550 metric tons/yr	Hydroscience, Incorporated
Total Urbanized Area	100,190 km^2	U.S Census Bureau (1973)
Unit area emissions rate, Q	0.0331 $\mu g/sec - m^2$	SAI computations
Average U. S. wind speed, u	5.5 m/sec	Mara and Lee (1978)
Average exposed concentration, χ	1.354 $\mu g/m^3$	SAI computations
Total population in Urbanized Areas in 1978	135 million*	U.S Census Bureau (1973)
Total U. S. annual dosage	1.88×10^8 ($\mu g/m^3$) - person	SAI computations

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* Based on 1970 population in Urbanized Areas, 127,270,000, and the projected 1978 to 1970 population ratio of 218 million/205 million.

Prototype Point Source Approach

In this approach, concentration-dosage patterns were estimated for emissions from three model sources--a CD, an OTVD, and a CVD--for the nine regions. The emissions rates of these three model sources were assumed to be constants, as shown in Table 19.

A set of STAR (STability ARray) stations with climatological conditions that are typical of those in the nine regions were selected as the base for conducting regional model source dispersion modeling (see Table 10).

Trichloroethylene is quite reactive toward ambient hydroxyl radical (OH)--about one-fifth as reactive as propylene. Its reaction with ozone molecules is, however, very slow. Therefore, the psuedo-first-order reaction rate constant of trichloroethylene in the ambient air in the daytime would be about 1.68×10^{-3} min^{-1}; during the night it would be close to zero since atmospheric reactions toward OH species occur only in the daytime.

Most of the trichloroethylene-using degreasing units--cold degreasers or vapor degreasers--are housed inside a building or other shelter. Emissions are from the venting system of the shelter. The emissions parameters for these three types of degreasers are summarized in Table 20.

TABLE 20. EMISSIONS PARAMETERS FOR PROTOTYPE POINT SOURCES OF TRICHLOROETHYLENE

Source Type	Vent Height (m)	Building Cross-Section (m^2)	Vent Diameter (m)	Vent Velocity (m/sec)	Vent Temperature (°K)
Cold cleaners	4.5	50	0.15	0.2	--
Open top vapor degreasers	4.5	50	0.15	0.2	327
Conveyorized vapor degreasers	4.5	50	0.15	0.2	327

Source: Hydroscience, Incorporated, Knoxville, Tennessee; trichloroethylene report, attached.

The major steps involved in deriving the exposure-dosage estimates can be delineated as follows:

> Based on emissions characteristics, photochemical reactivity, and the STAR data of the selected stations, the concentration patterns resulting from emissions from the three model sources were determined individually for all nine regions by using the same dispersion modeling technique developed for major point sources. As an example, the modeling results of concentration patterns around a model OTVD in the New England Region are shown in Table 21.

> Table 22 lists the distances between the concentration centers (receptors) and the source, the distances of boundary areas of the sectors away from the source, and the land area of sectors corresponding to each concentration center. The average population density in the urbanized areas for the nine regions, together with the specific sector land area assigned to each concentration center, were used to estimate the population exposed to different concentrations. To make this estimate, the average population density is multiplied by the sector land area corres-

TABLE 21. TRICHLOROETHYLENE CONCENTRATION PATTERN AROUND A MODEL OPEN TOP VAPOR DEGREASER IN NEW ENGLAND REGION

($\mu g/m^3$)

Wind Direction*	Downwind Distance From the Source (km)									
	0.2	0.3	0.5	0.7	1.0	2.0	5.0	10.0	15.0	20.0
1	2.617	1.180	0.390	0.1752	0.0697	0.00867	2.04×10^{-4}	3.23×10^{-6}	1.30×10^{-7}	8.3×10^{-9}
2	1.017	0.455	0.149	0.0662	0.0262	0.00327	0.86×10^{-4}	1.71×10^{-6}	0.83×10^{-7}	6.0×10^{-9}
3	1.066	0.481	0.159	0.0720	0.0291	0.00386	1.11×10^{-4}	2.50×10^{-6}	1.33×10^{-7}	10.1×10^{-9}
4	1.013	0.458	0.152	0.0688	0.0277	0.00357	0.93×10^{-4}	1.74×10^{-6}	0.80×10^{-7}	5.6×10^{-9}
5	2.190	0.990	0.330	0.1490	0.0604	0.00776	1.87×10^{-4}	2.89×10^{-7}	1.18×10^{-7}	7.9×10^{-9}
6	1.854	0.831	0.273	0.1223	0.0486	0.00608	1.41×10^{-4}	1.98×10^{-6}	0.68×10^{-7}	3.9×10^{-9}
7	1.259	0.551	0.173	0.0745	0.0280	0.00295	0.48×10^{-4}	0.42×10^{-6}	0.85×10^{-7}	0.26×10^{-9}
8	0.882	0.388	0.122	0.0525	0.0196	0.00201	0.31×10^{-4}	0.29×10^{-6}	0.79×10^{-7}	0.40×10^{-9}
9	2.629	1.182	0.388	0.1732	0.0681	0.00809	1.65×10^{-4}	2.12×10^{-6}	0.73×10^{-7}	4.28×10^{-9}
10	1.888	0.869	0.298	0.1384	0.0575	0.00789	2.11×10^{-4}	3.42×10^{-6}	1.30×10^{-7}	7.71×10^{-9}
11	1.897	0.876	0.302	0.1414	0.0591	0.00823	2.21×10^{-4}	3.42×10^{-6}	1.26×10^{-7}	7.50×10^{-9}
12	2.737	1.260	0.434	0.2026	0.0845	0.01160	2.95×10^{-4}	4.18×10^{-6}	1.40×10^{-7}	7.71×10^{-9}
13	2.854	1.325	0.464	0.2202	0.0943	0.01412	4.50×10^{-4}	8.95×10^{-6}	4.11×10^{-7}	28.4×10^{-9}
14	2.912	1.362	0.480	0.2245	0.0988	0.01485	4.79×10^{-4}	9.98×10^{-6}	4.73×10^{-7}	33.1×10^{-9}
15	2.771	1.283	0.445	0.2090	0.0879	0.01243	3.50×10^{-4}	6.03×10^{-6}	2.45×10^{-7}	15.5×10^{-9}
16	1.838	0.841	0.284	0.1308	0.0535	0.00702	1.70×10^{-4}	2.36×10^{-6}	0.79×10^{-7}	4.4×10^{-9}

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* 1 = N, 2 = NNE, 3 = NE, etc.

Source: Systems Applications, Incorporated computations.

TABLE 22. LAND AREAS FOR SPECIFIED CONCENTRATION CENTERS

Distance of Concentration Center from Source (km)	Distance of Boundary Arc from Source, r (km)	πr^2 (km^2)	Land Area of Sector, $\Delta \pi r^2/16$ (km^2)
	0.1*	0.0314	
0.2			0.0103
	0.25	0.196	
0.3			0.0192
	0.4	0.503	
0.5			0.0393
	0.6	1.131	
0.7			0.071
	0.85	2.270	
1.0			0.300
	1.5	7.069	
2.0			1.963
	3.5	38.48	
5.0			8.64
	7.5	176.7	
10.0			19.64
	12.5	490.9	
15.0			29.44
	17.5	962.0	
20.0			39.25
	22.5	1590.0	

---

* The radius of prototype plant property is assumed to be 100 meters.

ponding to the specific concentration center. The dosage corresponding to the specific concentration center can then be estimated by multiplying the exposed population by the concentration to which it is exposed. Therefore, for each model source in each of the nine regions, there were three corresponding matrices--one for the concentration pattern, one for the exposed population, and one for the dosage estimates.

The exposure-dosage data for each model source were then summarized according to their corresponding exposed concentration. The population exposed to concentrations greater than or equal to each of a number of concentration levels, L_j, in the vicinity of a model source m in region r was computed by:

$$e_{m,r} = \sum_{i=1}^{N} P_i S_i \ (C_i, L_j) \quad , \qquad (17)$$

where

N = the total number of concentration points (with 10 receptors along each of 16 wind directions: 10 x 16 = 160),

P_i = the population corresponding to concentration center i,

C_i = the annual average exposed concentration at concentration center i,

$$S_i = \begin{cases} 0, \text{ if } C_i < L_j \\ 1, \text{ if } C_i \geq L_j \end{cases} \quad .$$

The population exposed to trichloroethylene concentrations larger than or equal to different concentration levels resulting from the three model sources in the nine regions is listed in Table 23. The dosage of the fraction of population that is exposed to concentrations greater than or equal to each of a number of concentration levels, L_j, in the vicinity of a model source m in region r was computed by:

$$d_{m,r} = \sum_{i=1}^{N} P_i C_i S_i \ (C_i, L_j) \quad . \qquad (18)$$

The dosages of trichloroethylene as a function of exposed concentration levels for the three types of model degreasers in the nine regions are shown in Table 24. The exposure-dosage patterns for each of the three model sources located in each of the nine regions can be used as the bases for estimating the total exposure-dosage as a function of exposed concentration levels in each individual region by:

$$(\text{Total exposure at } L_j)_r = \sum_{m=1}^{3} (e_{m,r} \times n_{m,r}) \quad , \qquad (19)$$

$$(\text{Total dosage at } L_j)_r = \sum_{m=1}^{3} (d_{m,r} \times n_{m,r}) \quad , \qquad (20)$$

TABLE 23. POPULATION EXPOSURE TO TRICHLOROETHYLENE EMITTED FROM A TYPICAL DEGREASER

(a) Cold Degreaser

Concentration Level ($\mu g/m^3$)	Number of Persons Exposed by Geographic Region								
	1	2	3	4	5	6	7	8	9
0.25	0	0	0	0	0	9	0	10	30
0.10	0	41	84	71	58	68	28	49	129
0.05	120	284	300	160	226	153	143	169	216
0.025	398	769	522	360	421	339	273	370	614

Source: Systems Applications, Incorporated computations.

TABLE 23 (Continued)

(b) Open Top Vapor Degreaser

Concentration Level (μg/m^3)	Number of Persons Exposed by Geographic Region								
	1	2	3	4	5	6	7	8	9
5.0	0	0	28	10	12	17	0	20	30
2.5	65	102	98	81	69	107	46	70	129
1.0	286	477	392	241	314	282	212	295	488
0.5	418	898	734	438	608	430	457	541	708
0.25	957	1,857	1,285	893	1,032	785	859	833	1,216
0.10	2,000	4,335	2,210	2,203	2,280	1,642	2,108	1,867	3,058
0.05	5,554	9,067	4,466	3,783	4,387	2,506	3,668	3,086	4,196
0.025	7,142	12,176	8,209	4,956	7,161	4,566	5,201	6,609	7,087

TABLE 23 (Concluded)

(c) Conveyorized Vapor Degreaser

Concentration Level ($\mu g/m^3$)	Number of Persons Exposed by Geographic Region								
	1	2	3	4	5	6	7	8	9
5.0	120	263	246	122	182	144	107	149	216
2.5	388	672	496	320	400	338	229	314	542
1.0	749	1,328	933	764	753	636	596	648	1,048
0.5	1,451	2,657	1,674	1,188	1,548	908	1,154	1,214	1,491
0.25	3,265	5,205	3,407	2,350	2,869	1,794	2,471	2,438	3,260
0.10	5,867	12,172	6,198	4,663	5,726	4,019	4,926	4,262	5,794
0.50	7,451	13,975	8,716	7,850	7,238	4,884	5,720	6,905	10,363
0.025	17,876	33,443	14,469	17,000	14,167	7,038	15,000	8,857	15,758

TABLE 24. TRICHLOROETHYLENE DOSAGE RESULTING FROM MODEL DEGREASER EMISSIONS

[(μg/m^3)/person]

(a) Cold Degreaser

Concentration Level (μg/m^3)	Geographic Region								
	1	2	3	4	5	6	7	8	9
0.25	0	0	0	0	0	2	0	3	8
0.10	0	5	12	9	8	9	4	8	19
0.05	9	22	27	15	19	16	11	16	25
0.025	19	38	34	22	26	22	16	23	38
0.010	25	50	42	28	33	27	22	28	47
0*	52	98	66	49	55	40	43	47	70

TABLE 24 (Continued)

(b) Open Top Vapor Degreaser

Concentration Level ($\mu g/m^3$)	Geographic Region								
	1	2	3	4	5	6	7	8	9
5.0	0	0	154	74	59	117	0	132	230
2.5	180	325	406	312	260	351	161	285	570
1.0	488	915	924	551	682	622	424	621	1,063
0.5	598	1,252	1,171	704	895	732	590	787	1,217
0.25	803	1,588	1,349	878	1,034	853	719	891	1,429
0.10	979	1,960	1,498	1,070	1,232	974	892	1,057	1,719
0*	1,579	2,953	1,998	1,478	1,671	1,211	1,296	1,420	2,109

TABLE 24 (Concluded)

(c) Conveyorized Vapor Degreaser

Concentration Level ($\mu g/m^3$)	Geographic Region								
	1	2	3	4	5	6	7	8	9
5.0	850	1,900	2,160	1,150	1,490	1,360	850	1,310	2,220
2.5	1,700	3,230	3,040	1,860	2,260	2,000	1,310	1,900	3,310
1.0	2,210	4,260	3,730	2,500	2,850	2,400	1,910	2,490	4,090
0.50	2,680	5,200	4,250	2,790	3,400	2,620	2,320	2,880	4,420
0.25	3,260	6,070	4,790	3,220	3,830	2,940	2,750	3,300	5,160
0.10	3,730	7,250	5,210	3,640	4,300	3,250	3,150	3,570	5,500
0*	4,700	8,810	5,950	4,400	4,980	3,620	3,850	4,220	6,300

---

* Total dosage resulting from emissions from one model source in a

where $n_{m,r}$ is the total number of model source m (a CD, an OTVD, or a CVD) in region r. On the other hand, the total nation-wide exposure-dosage resulting from emissions from one type of model source can be derived by

$$(\text{Total exposure at } L_j)_m = \sum_{m=1}^{9} (e_{m,r} \times n_{m,r}) \quad , \qquad (21)$$

$$(\text{Total dosage at } L_j)_m = \sum_{r=1}^{9} (d_{m,r} \times n_{m,r}) \quad . \qquad (22)$$

The following two equations were used to estimate the total U.S. exposure-dosage for the fraction of the population exposed to concentrations of trichloroethylene greater than or equal to a number of concentration levels, L_j, emitted from this source category:

$$\text{Total exposure at } L_j = \sum_{r=1}^{9} \sum_{m=1}^{3} (e_{m,r} \times n_{m,r}) \quad , \qquad (23)$$

$$\text{Total dosage at } L_j = \sum_{r=1}^{9} \sum_{m=1}^{3} (d_{m,r} \times n_{m,r}) \quad . \qquad (24)$$

The results of such summations are shown in Tables 25, 26, and 27.

The two different approaches for computing total dosages resulting from emissions from trichloroethylene-using degreasers produce different results. By using the uniform emissions approach, the total U.S. dosage of trichloroethylene resulting from degreasing operations is computed to be 1.88×10^8 μg/m^3 - person (see Table 19), whereas use of the point source approach results in a dosage of 2.28×10^7 μg/m^3 - person (see Table 27). The two approaches can be compared by examining the nature and detail of the results they offer:

> Degreasing facilities are obviously not uniformly distributed in any siting area. They are point sources and produce typical point source concentration patterns. Thus, the exposure levels for receptors close to the source would be higher than those farther away. The point source approach would provide better differentiation of the exposed population and dosage at different concentration levels, whereas the uniform emissions approach would provide only a nationwide average exposure level. Tables 23, 24, and 27 list the exposure-dosage by different types of degreasers. These types of data are useful for risk analysis and regulatory decision making. For example, one may conclude from data listed in Table 27 that, although open top vapor degreasers contribute most to the total dosages, the conveyorized vapor degreasers contribute most to the dosage-exposure at high concentration levels.

> The dosage is defined here as the product of concentration and exposed population. Therefore, it is necessary to set an arbitrary boundary for dispersion-dosage estimates for emissions from point sources. In the point-sources

TABLE 25. NATIONWIDE TRICHLOROETHYLENE EXPOSURE RESULTING FROM EMISSIONS FROM DEGREASING OPERATIONS

Concentration Level (µg/m^3)	Thousands of Persons Exposed by Geographic Region									U.S. Total
	1	2	3	4	5	6	7	8	9	
5.0	14	64	148	144	21	12	7	7	62	349
2.5	79	282	371	624	66	42	34	19	205	1,160
1.0	245	876	1,060	1,700	209	108	125	65	610	3,470
0.5	398	1,690	1,960	2,930	413	161	260	120	880	6,170

Source: Systems Applications, Incorporated computations.

TABLE 26. NATIONWIDE TRICHLOROETHYLENE DOSAGE RESULTING FROM EMISSIONS FROM DEGREASING OPERATIONS

[10^6 (μg/m^3) - person]

Concentration Level (μg/m^3)	Geographic Region									U.S. Total
	1	2	3	4	5	6	7	8	9	
5.0	0.10	0.46	1.14	0.13	0.15	0.10	0.06	0.05	0.57	2.76
2.5	0.29	1.17	1.94	0.29	0.31	0.20	0.15	0.09	1.06	5.50
1.0	0.52	2.10	3.12	0.45	0.57	0.29	0.30	0.16	1.63	9.13
0.50	0.64	2.72	3.77	0.54	0.70	0.33	0.39	0.20	1.82	11.10
0.25	0.82	3.32	4.29	0.66	0.80	0.39	0.47	0.23	2.17	13.20
0.10	0.97	4.08	4.88	0.82	0.98	0.45	0.59	0.27	2.56	15.60
0.05	1.16	4.63	5.47	0.91	1.13	0.49	0.67	0.31	2.70	17.50
0.025	1.26	5.07	5.86	0.98	1.24	0.54	0.74	0.34	2.91	18.90
0.010	1.38	5.56	6.07	1.07	1.31	0.56	0.83	0.36	3.09	20.20
0*	1.57	6.33	6.76	1.23	1.53	0.63	0.99	0.42	3.34	22.80

---

* Total dosage, assuming the exposed area is within 22.5 km radius of the source.

Source: Systems Applications, Incorporated computations.

TABLE 27. NATIONWIDE TRICHLOROETHYLENE EXPOSURES AND DOSAGES RESULTING FROM EMISSIONS FROM DIFFERENT TYPES OF DEGREASING FACILITIES

Concentration Level ($\mu g/m^3$)	Exposure (10^6 persons exposed)				Dosage [10^6 ($\mu g/m^3$) - person]			
	CD*	OTVD†	CVD§	Total	CD	OTVD	CVD	Total
5.0	0	0.09	0.26	0.35	0	0.59	2.17	2.76
2.5	0	0.57	0.59	1.16	0	2.17	3.33	5.50
1.0	0	2.30	1.17	3.47	0	4.91	4.22	9.13
0.50	0	4.06	2.11	6.17	0	6.22	4.89	11.1
0.25	--	--	--	--	0.06	7.46	5.63	13.2
0.10	--	--	--	--	0.46	8.83	6.31	15.6
0.05	--	--	--	--	1.01	9.93	6.53	17.5
0.025	--	--	--	--	1.46	10.60	6.92	18.9
0.010	--	--	--	--	1.84	11.20	7.20	20.2
0**	--	--	--	--	3.15	12.20	7.43	22.8

---

* Cold degreaser.

† Open top degreaser.

§ Conveyorized vapor degreaser.

** Total dosage, assuming the exposed area is within 22.5 km radius of the source.

Source: Systems Applications, Incorporated computations.

approach, the impact area of one model source is defined as being within a 22.5 km radius of the source. As revealed by the data in Tables 26 and 27 , dosages decrease rapidly with decreasing concentration levels; thus, dosages also decrease dramatically as one moves farther away from the source. This convergency nature of the dosages as a function of concentrations indicates that the dosages contributed by exposures outside the arbitrarily defined impact areas ($r < 22.5$ km) would not be significant compared to the total dosage within the impact area.

The total dosage for a specified population can be estimated by using either of the following two methods:

> Estimate the dosage resulting from emissions from each nearby source and sum them.
> Estimate the overall exposed concentration level and then compute the total dosage.

Since the overall exposed concentration level cannot be derived because of the lack of data on geographical distributions of sources, the first method was used here.

By examining the results derived from adoption of the two approaches and considering the above information, the study team concluded that the point source approach would be more appropriate for dealing with all general point sources in this study. However, not all the data involved would be listed in each individual chemical exposure-dosage summary, and only the modeling results and the major input data, such as the number of sources in each region and the emissions characteristics, would be delineated.

AREA SOURCE MODELING APPROACH

Certain of the chemicals to be studied in the Human Exposure program are emitted from area sources that cannot be specified in detail; such emissions must be inferred by relating them to population, motor vehicles, etc. However, different urbanized areas with different levels of population/motor vehicles concentrations are likely to be exposed to different levels of these ambient chemicals under different environmental settings. Because the number of urbanized areas to be studied is quite large, it is necessary to use a simple dispersion algorithm to estimate concentration patterns. The Hanna-Gifford urban area dispersion algorithm (Hanna, 1971; Hanna and Gifford, 1973) has proved to be a simple but physically realistic model capable of estimating atmospheric pollutant concentrations caused by area source emissions in cities. The basic Hanna-Gifford Equation is given as:

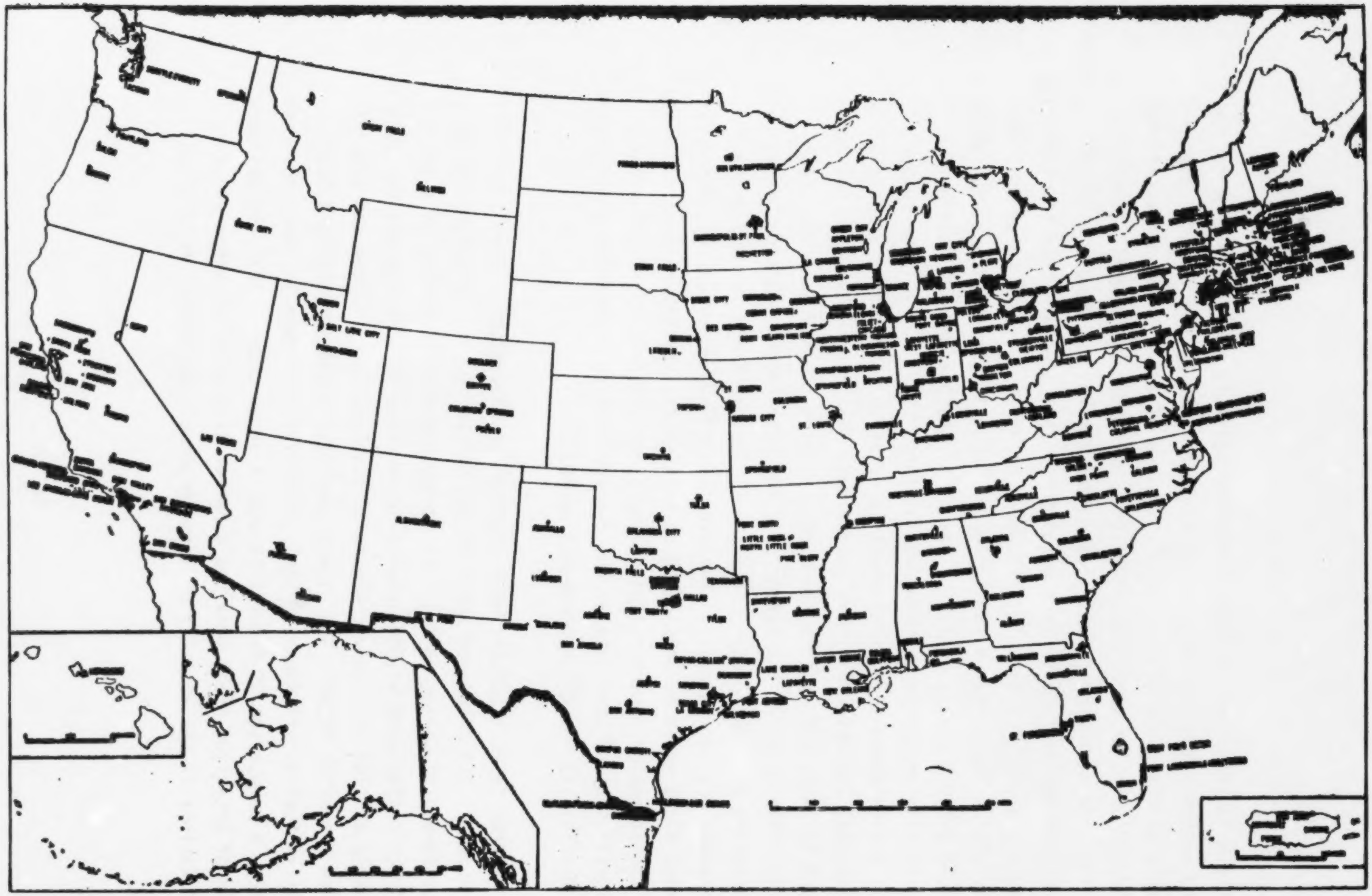
$$X = CQ_0/\mu \quad , \qquad (25)$$

where X is the air pollutant concentration, Q_0 is the effective emissions rate per unit area, and μ is the average wind speed. The parameter C, generally referred to as the Hanna-Gifford coefficient, is a weak function of the city size; it may be taken to be approximately constant. Theoretically, the parameter C is given by:

$$C = (2/\pi)^{1/2} \cdot x^{1-b} / [a(1-b)]^{-1} \quad , \qquad (25)$$

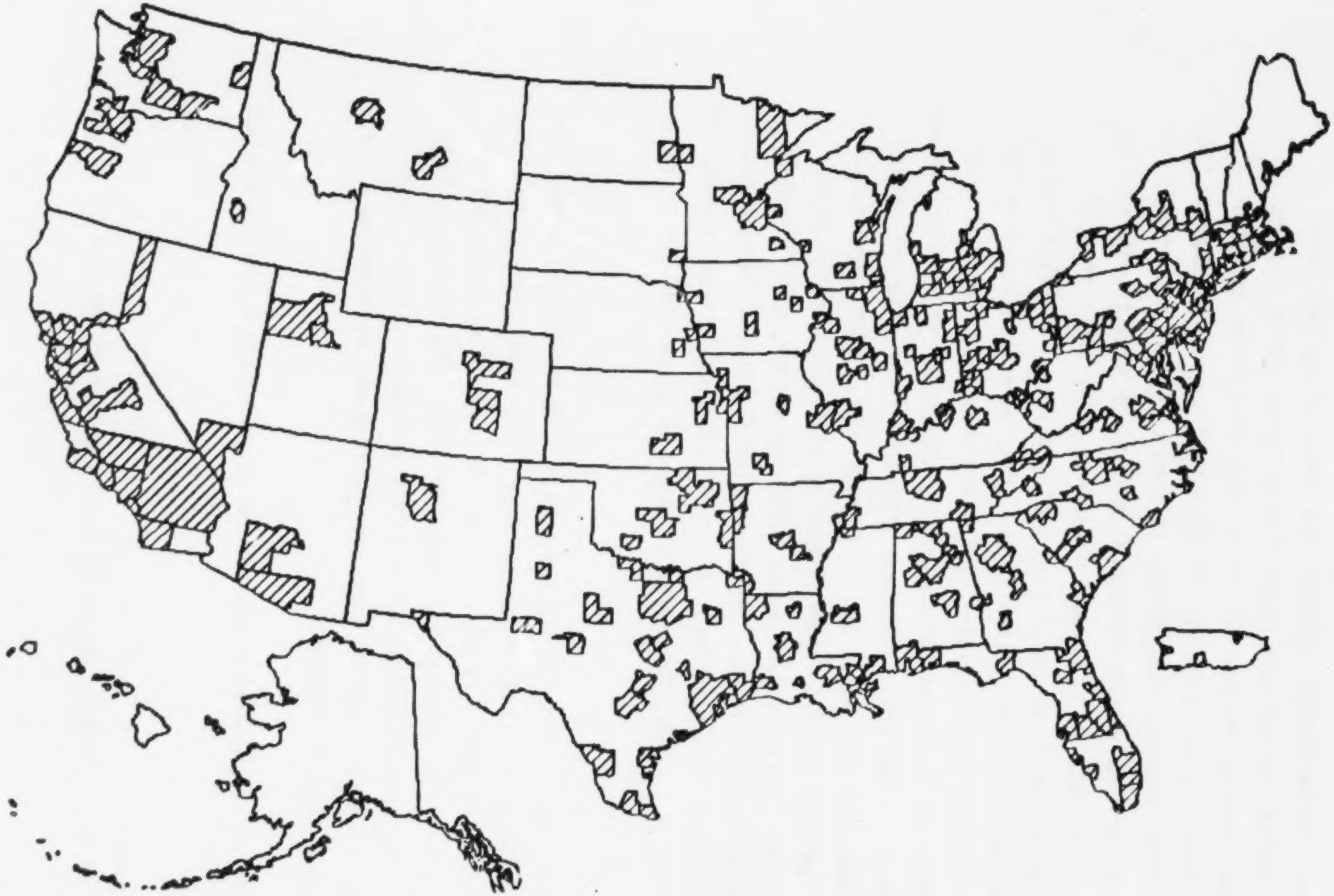
where χ is the distance from a receptor point to the upwind edge of the area source. The constants a and b are defined by the vertical atmospheric diffusion length, $\sigma_z = a\chi^b$. Values of a and b for different atmospheric dispersion conditions have been discussed by Pasquill (1970, 1971). The parameter C can be estimated for various combinations of the stability factors a and b and by assuming that χ equals half the city size (Hanna, 1978). For example, 213 would be an appropriate value of C for a city with a land area of 400 km^2 under Pasquill Class D stability (while a = 0.15 and b = 0.75). Specific values of the parameter C have been empirically estimated by Hanna and Gifford (1973) for a large number of U.S. cities based on a large quantity of air quality data, average annual emissions, and meteorological conditions. The mean value of C has been found to equal 225, with a standard deviation roughly half that magnitude. This value of the parameter C has been recommended for use in evaluating an area source by the EPA (1977a,b) if removal and decay processes may be neglected. Because a large number of cities with different sizes would be considered in this study, the theoretical estimates of the parameter C were calculated by using Equation 2 and by assuming Pasquill Class D stability as the average long-term meteorological condition. This is the EPA-recommended approach.

Three types of cities were assessed in this study. Type I cities include all 248 Urbanized Areas in the United States, as determined by the U.S. Bureau of Census (1973). An "Urbanized Area" consists of a central city or cities with 50,000 inhabitants or more in 1960 and the surrounding densely settled territory. Figure 13 displays the location and size of these Urbanized Areas. The widely used data bases for Standard Metropolitan Statistical Areas (SMSAs), displayed in Figure 14, were not used here. A comparison of Figures 13 and 14 shows clearly that the delineation of Urbanized Areas provides a better separation of urban and rural populations in the vicinity of large metropolitan areas. Most of the



Source: U.S. Census Bureau (1973).

FIGURE 13. U.S. URBANIZED AREAS (1970)



Source: U.S. Federal Highway Administration (1974).

FIGURE 14. U.S. STANDARD METROPOLITAN STATISTICAL AREAS (1970)

Urbanized Areas can be further divided into inner cities and urban fringe. The central cities were classified as inner cities and any Urbanized Areas outside the central cities were classified as urban fringe. The latest census data for the Urbanized Areas are based on the 1970 census survey results (U.S. Bureau of Census, 1973); accordingly, 1970 population data were used throughout this study even though more up-to-date population data (U.S. Bureau of Census, 1978) are currently available at other levels of population unit/grouping. The 1973 statistics on motor vehicle registrations in the SMSAs were obtained from the U.S. Federal Highway Administration (1974) and were used, together with population data, as the bases for estimating the number of automobiles and trucks and buses in the Urbanized Areas (for both inner city and urban fringe). These 1970 population and 1973 motor vehicle data were subsequently extrapolated to 1978 figures based on statistics at the state level. Table 28* lists the land areas, 1970 population, and 1973 motor vehicle data for Type I cities. The statistics for trucks include buses and all other heavy duty vehicles. The total 1970 population in these 248 Urbanized Areas is 118,446,000, which is about 59 percent of the total U.S. population.

Type II cities include all cities with a 1970 population larger than 25,000 but not located in any Urbanized Area. The total population residing in the 243 Type II cities is 8,594,000, which is about 4.3 percent of the total U.S. population. Table 29* lists the land area, the 1970 population, and 1973 motor vehicle data for these cities. These Type II city estimates used the same data sources and methodology as were used for Type I city estimations.

Type III cities have 1970 populations of more than 2,500 but are not included in Type I and Type II cities. There are over 1,000 cities and towns in the United States in this category. Therefore, a sample of 150 cities of this type was pulled from the list (U.S. Bureau of Census, 1973, Table B-2) using a random numbers table. Table 30* lists the land area, 1970 population, and 1973 motor vehicle data for these 150 cities and towns. The motor vehicle data estimates were based on statistics at the state level. The total population of these 150 cities and towns is 1,077,000 in 1970. It is about 5 percent of the total population (21,708,000) in all Type III cities. The exposure-dosage data estimated for the 150 cities/towns were scaled by the ratio of all Type III population to the sample population so as to represent exposure-dosage for all Type III cities. Type III cities represented about 11 percent of the total U.S. population in 1970.

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* Because of their length, Tables 28 and 29 appear at the end of Section 3.

Most of the U.S. population (about 75 percent) is included in cities of Type I, II, or III. Chemical exposure-dosage in areas not represented is deemed insignificant because of the low concentrations and low population densities. As evidenced later in this report, this assumption--that less densely populated areas would be exposed to insignificant ambient concentrations--is valid. The atmospheric concentrations of chemicals resulting from area source emissions were shown to be much lower for residents in Type III cities than those in Type I cities. Rural population densities and, therefore, rural concentrations are even lower.

Chemical emissions from area sources of various categories are estimated and reported as national totals in the emissions summaries submitted by HI. These national total emissions estimates have to be distributed among cities of each of the three types. Depending on the nature of emitting sources, the distribution can be accomplished by one of the following methods:

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* Because of its length, Table 30 appears at the end of Section 3.

> Emissions from mobile sources can be distributed by the number of motor vehicles.

> Emissions from home heating sources can be distributed by the product of population and per capita heating requirement.

> Other stationary area sources can be distributed by population.

Table 31 lists, in addition to those data listed in Tables 28, 29, and 30, the necessary data for area source emissions distributions. These include the 1970 and 1978 state population data (U.S. Bureau of Census, 1979), 1973 and 1978 state motor vehicle data (U.S. Federal Highway Administration, 1978), statewide average wind speed, and state-wide average heating requirements in degree-days (U.S. Bureau of Census, 1979). The 1978 figures are estimates, as population/motor vehicle data for each of the three types of cities are not available for 1978. These data at the state level were used to project the growth. For example, Anniston, Alabama, is a Type II city with city code 1 (as shown in Table 29). Its 1970 population was 31,058, and there were 16,800/3,692 autos/trucks registered in 1973. To estimate the 1978 statistics, the state growth during the same period (as shown in Table 31) was used. The 1978 population in this city is estimated to be 31,508 x (3,724,000/3,444,000) = 34,070. The 1978 auto/truck figure can be estimated in the same way: 16,899 x (2,791,000/2,299,000) = 20,515; 3,692 x (2,791,000/2,299,000) = 4,482.

Three equations were used to distribute the area sources into each of the three types of cities (or urbanized areas). For mobile sources,

$$Q_M = \frac{EM}{A} \cdot \frac{a78 + t78 \cdot R}{117{,}147{,}000 + 31{,}921{,}000 \cdot R} \quad , \qquad (27)$$

TABLE 31. MAJOR STATE STATISTICS RELATED TO AREA SOURCE EMISSIONS DISTRIBUTION

State	Population* (in thousands)		No. of Vehicles† (in thousands)		Average Wind Speed§ (m/sec)	Average Heating§ (degree-day/year)
	1970	1978	1973	1978		
Alabama	3,444	3,724	2,299	2,791	4.4	1,684
Alaska	300	420	180	280	4.0	9,007
Arizona	1,771	2,365	1,379	1,630	3.0	1,552
Arkansas	1,923	2,176	1,195	1,501	3.9	3,354
California	19,953	22,153	13,238	15,514	4.1	2,568
Colorado	2,207	2,674	1,757	2,303	4.3	6,016
Connecticut	3,032	3,119	1,927	2,133	4.2	6,350
Delaware	548	587	336	385	4.3	4,940
D.C.	757	680	262	261	4.4	4,211
Florida	6,789	8,687	5,242	6,345	4.2	767
Georgia	4,590	5,116	3,079	3,670	4.3	3,095
Hawaii	769	912	465	544	5.6	0
Idaho	713	878	597	762	4.3	5,833
Illinois	11,114	11,265	5,940	7,127	4.9	6,298
Indiana	5,194	5,348	3,156	3,720	4.6	5,577
Iowa	2,824	2,886	1,980	2,301	5.3	6,710
Kansas	2,247	2,335	1,726	1,981	6.0	4,687
Kentucky	3,219	3,491	2,064	2,549	4.0	4,645
Louisiana	3,641	3,958	2,037	2,504	4.0	1,465
Maine	992	1,096	605	751	4.2	7,498
Maryland	3,922	4,168	2,228	2,674	4.5	4,729
Massachusetts	5,689	5,795	2,838	3,621	6.0	5,621
Michigan	9,875	9,158	5,193	6,252	4.7	7,710
Minnesota	3,805	3,998	2,451	2,897	5.2	8,958
Mississippi	2,217	2,414	1,285	1,544	3.6	2,300
Missouri	4,677	4,818	2,710	3,125	4.7	4,956
Montana	697	774	560	761	6.2	7,652
Nebraska	1,483	1,570	1,102	1,247	5.2	6,049
Nevada	489	655	431	583	3.1	6,002
New Hampshire	738	842	465	591	3.2	7,360
New Jersey	7,168	7,349	4,023	4,534	5.1	4,946
New Mexico	1,016	1,214	732	945	4.3	4,292
New York	18,237	17,874	7,273	7,851	4.9	6,221
North Carolina	2,488	2,992	3,384	4,273	3.7	3,366
North Dakota	618	659	502	595	5.0	9,044
Ohio	10,652	10,702	6,717	7,766	4.5	5,642
Oklahoma	2,559	2,846	1,959	2,361	6.1	3,692
Oregon	2,091	2,417	1,527	1,845	3.7	4,792
Pennsylvania	11,794	11,776	6,836	8,183	4.5	5,398
Rhode Island	947	930	548	690	5.1	5,972
South Carolina	2,591	2,917	1,593	1,941	3.3	2,598
South Dakota	666	692	487	585	5.3	7,838
Tennessee	3,924	4,350	2,439	3,177	4.1	3,462
Texas	11,197	13,062	7,713	10,021	4.4	2,165
Utah	1,059	1,298	774	941	4.1	5,983
Vermont	444	489	269	336	4.2	7,876
Virginia	4,648	5,200	2,944	3,330	4.3	3,714
Washington	3,409	3,689	2,358	3,048	4.3	6,010
West Virginia	1,744	1,875	902	1,170	3.1	4,590
Wisconsin	4,418	4,684	2,479	2,734	5.6	7,444
Wyoming	332	417	292	395	6.3	7,255
U.S. Total	200,621	215,494	124,478	149,068		

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* Source: U.S. Census Bureau (1979).

† Source: U.S. Federal Highway Administration (1978).

§ Source: U.S. Census Bureau (1979)

where

EM is the national total mobile source emissions ([g/sec) of the chemical,
A is the land area of the city (m^2),
a78 is the 1978 estimated number of automobiles in the city,
t78 is the 1978 estimated number of trucks/buses in the city,
R is the ratio of average truck emissions to the average automobile emissions,
117,147,000 is the 1978 estimated national total number of automobiles,
31,921,000 is the 1978 estimated national total number of trucks/buses.

For heating sources,

$$Q_H = \frac{EH}{A} \cdot \frac{P78 \cdot HR}{215{,}494{,}000 \cdot 4633} \quad , \qquad (28)$$

where

EH is the national total heating source emissions (μg/sec) of the chemical,
P78 is the 1978 estimated population in the city,
HR is heating requirements (degree-days/yr),
215,494,000 is the total U.S. population (excluding military service) in 1978,
4633 is the population-weighted nationwide per-capita heating requirement (degree-days/year).

For nonheating stationary sources,

$$Q_N = \frac{EN}{A} \cdot \frac{P78}{215,494,000} \quad , \qquad (29)$$

where EN is the national total emissions from nonheating stationary area sources (μg/sec).

These three types of emissions can be summarized as the total area source emissions in the specific city. Some of the chemicals may undergo chemical decay in the ambient air. Therefore, the effective emissions rates must be estimated, taking consideration of the decay factor. The pseudo-first-order decay constants used in estimating effective emissions rates in the dispersion modeling of point source emissions were applied here also. The average time, t, that wind-blown pollutant remains within a city was estimated by assuming the average travel distance to be half the size of the city and the wind to be at its annual average speed. The average of the daytime and nighttime effective emissions rates was used as the overall effective emissions rate, Q_o, in Equation 1 in estimating the annual average concentration. The equation used in deriving the effective emissions rate is:

$$Q_o = (Q_M + Q_H + Q_W) \cdot [\exp(-Kd\frac{\sqrt{A/2}}{\mu}) + \exp(-Kn\frac{\sqrt{A/2}}{\mu})]/2 \quad , \qquad (30)$$

where Kd is the daytime chemical decay rate (sec^{-1}), Kn is the nighttime chemical decay rate (sec^{-1}), and μ is the average wind speed (m/sec).

The total dosage of ambient chemical in a specific city can be estimated by multiplying the average ambient concentration of the chemical, x, by the estimated 1978 population of that city. These exposure-dosage data for all three types of cities can be summarized at different exposure levels. The contribution of each of the three types of area emissions to the total dosage can also be estimated for each city and for all cities as a whole. The distribution of national total dosages among the three types of cities can also be estimated.

A computer program has been coded to conduct the estimation and data summarization as described above. Beryllium emitted from area sources was used as an example to exercise the program and to illustrate the nature and details of the estimated results. Table 32 lists the data input required for estimating the exposure-dosage resulting from area source emissions of beryllium. Tables 33, 34, and 35 list the annual average ambient concentration computed with the box model, the estimated 1978 population, the total resulting dosages, and the percentage contribution of total dosage by the different types of area sources for each of three types of cities. The overall national total beryllium exposure and dosage resulting from area source emissions are listed in Table 36.

This approach was used to estimate the human exposure and dosages resulting from chemical emissions from area sources in this study.

TABLE 32. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF BERYLLIUM

Parameter	Value (gm/sec)	Sources
Daytime decay rate (K_d)	0	Section 2
Nighttime decay rate (K_n)	0	Section 2
Hanna-Gifford coefficient (C)	225	EPA, 1977
Nationwide heating source emissions (E_H)	0.203	
Residential/commercial coal burning	0.058	
Residential/commercial oil burning	0.145	
Nationwide nonheating stationary source emissions (E_N)	0.538	
Coal-burning	0.396	
Oil-burning	0.142	
Nationwide mobile source emissions (E_M)	0.0693	
Ratio of truck emissions to auto emissions (R_M)	3.0	

TABLE 33. BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS IN TYPE I CITIES

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION		
							HEATING	STATIONARY	MOBILE
1	1	ABIENE,TX	INNER CITY	.000078	104391	8.2	13.3	75.3	11.4
			URBAN FRINGE	.000015	1265	.0	13.3	75.3	11.4
1	2	AKRON,OH	INNER CITY	.000320	276712	88.5	29.2	63.6	7.2
			URBAN FRINGE	.000128	268619	34.3	29.2	63.6	7.2
1	3	ALBANY,GA	INNER CITY	.000144	80945	11.7	18.5	73.5	8.0
			URBAN FRINGE	.000049	4334	.2	18.5	73.5	8.0
1	4	ALBANY,NY	INNER CITY	.000348	251548	87.5	31.8	62.7	5.5
			URBAN FRINGE	.000133	225292	29.9	31.8	62.7	5.5
1	5	ALBUQUERQUE,NM	INNER CITY	.000232	291253	67.5	23.5	67.3	9.2
			URBAN FRINGE	.000118	64165	7.6	23.5	67.3	9.2
1	6	ALLENTOWN,PA	INNER CITY	.000303	212136	64.2	28.4	64.6	7.0
			URBAN FRINGE	.000164	150879	24.7	28.4	64.6	7.0
1	7	ALTOONA,PA	INNER CITY	.000340	62802	21.4	28.4	64.6	7.0
			URBAN FRINGE	.000087	18860	1.6	28.4	64.6	7.0
1	8	AMARILLO,TX	INNER CITY	.000129	142332	18.4	13.2	74.7	12.2
1	9	ANDERSON,IN	INNER CITY	.000115	72953	8.4	28.9	63.7	7.4
			URBAN FRINGE	.000080	10143	.8	28.9	63.7	7.4
1	10	ANN ARBOR,MI	INNER CITY	.000279	102979	28.8	36.2	57.7	6.1
			URBAN FRINGE	.000209	81320	17.0	36.2	57.7	6.1
1	11	APPLETON,WI	INNER CITY	.000217	60862	13.2	35.8	59.0	5.2
			URBAN FRINGE	.000155	76850	11.9	35.8	59.0	5.3
1	12	ASHEVILLE,NC	INNER CITY	.000188	69233	13.0	19.6	71.5	8.9
			URBAN FRINGE	.000066	17894	1.2	19.6	71.5	8.9
1	13	ATLANTA,GA	INNER CITY	.000270	553981	149.5	18.3	72.5	9.2
			URBAN FRINGE	.000176	753193	132.9	18.3	72.5	9.2
1	14	ATLANTIC CITY,NJ	INNER CITY	.000177	49098	8.7	26.8	66.6	6.6
			URBAN FRINGE	.000087	88301	7.7	26.8	66.6	6.6
1	15	AUGUSTA,GA	INNER CITY	.000212	66724	14.2	18.5	73.3	8.3
			URBAN FRINGE	.000128	99298	12.7	18.5	73.3	8.3
1	16	AURORA,IL	INNER CITY	.000255	131754	33.6	31.3	61.1	7.5
			URBAN FRINGE	.000128	104327	13.3	31.3	61.1	7.5
1	17	AUSTIN,TX	INNER CITY	.000223	293760	65.6	13.6	76.9	9.5
			URBAN FRINGE	.000047	14794	.7	13.6	76.9	9.5
1	18	BAKERSFIELD,CA	INNER CITY	.000160	77179	12.3	15.5	73.9	10.7
			URBAN FRINGE	.000211	119508	25.2	15.5	73.9	10.7
1	19	BALTIMORE,MD	INNER CITY	.000766	962571	737.1	26.0	67.6	6.3
			URBAN FRINGE	.000221	716298	158.0	26.0	67.6	6.3
1	20	BATON ROUGE,LA	INNER CITY	.000247	180420	44.6	9.5	79.4	11.1
			URBAN FRINGE	.000114	90762	10.3	9.5	79.4	11.1
1	21	BAY CITY,MI	INNER CITY	.000275	51025	14.0	36.1	57.4	6.5
			URBAN FRINGE	.000106	29561	3.1	36.1	57.4	6.5

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION		
							HEATING	STATIONARY	MOBILE
1	22	BEAUMONT, TX	INNER CITY	.000104	135280	14.1	13.5	76.4	10.1
			URBAN FRINGE	.000005	449	.0	13.6	77.3	9.0
1	23	BILLINGS, MONT	INNER CITY	.000206	68384	14.1	34.5	55.4	10.1
			URBAN FRINGE	.000038	10678	.4	34.5	55.4	10.1
1	24	BILOXI, MS	INNER CITY	.000162	97165	15.7	14.4	77.1	8.5
			URBAN FRINGE	.000078	35534	2.8	14.4	77.1	8.4
1	25	BINGHAMTON, NY	INNER CITY	.000277	62846	17.4	31.7	62.6	5.7
			URBAN FRINGE	.000141	101048	14.2	31.7	62.6	5.7
1	26	BIRMINGHAM, AL	INNER CITY	.000223	325133	72.7	10.8	78.9	10.3
			URBAN FRINGE	.000113	278339	31.4	10.8	78.9	10.3
1	27	BLOOMINGTON, IL	INNER CITY	.000221	66929	14.8	31.3	61.1	7.5
			URBAN FRINGE	.000031	3131	.1	31.4	61.1	7.5
1	28	BOISE CITY, ID	INNER CITY	.000239	92343	22.0	29.7	62.6	7.7
			URBAN FRINGE	.000113	12544	1.4	29.7	62.6	7.7
1	29	BOSTON, MASS	INNER CITY	.000654	652997	427.1	29.2	63.8	6.9
			URBAN FRINGE	.000211	2049001	433.1	29.2	63.8	6.9
1	30	BOULDER, CO	INNER CITY	.000354	81019	28.7	30.0	61.3	8.7
			URBAN FRINGE	.000088	2137	.2	30.0	61.3	8.7
1	31	BRIDGEPORT, CONN	INNER CITY	.000594	161037	95.6	31.8	61.5	6.7
			URBAN FRINGE	.000154	264189	40.6	31.8	61.5	6.7
1	32	BRISTOL, CONN	INNER CITY	.000136	57079	7.7	31.8	61.5	6.7
			URBAN FRINGE	.000090	16711	1.5	31.8	61.5	6.7
1	33	BROCKTON, MASS	INNER CITY	.000179	90699	16.2	29.2	63.8	6.9
			URBAN FRINGE	.000084	60918	5.1	29.2	63.8	6.9
1	34	BROWNSVILLE, TX	INNER CITY	.000191	64892	12.4	13.8	78.3	7.9
1	35	BRYAN, TX	INNER CITY	.000107	39335	4.2	13.6	77.1	9.3
			URBAN FRINGE	.000058	20620	1.2	13.6	77.1	9.3
1	36	BUFFALO, NY	INNER CITY	.000624	453571	282.8	32.0	63.1	4.9
			URBAN FRINGE	.000240	611394	147.0	32.0	63.1	4.9
1	37	CANTON, OH	INNER CITY	.000320	110455	35.3	29.2	63.5	7.3
			URBAN FRINGE	.000147	134970	19.8	29.2	63.6	7.2
1	38	CEDAR RAPIDS, IOWA	INNER CITY	.000126	113071	14.2	32.7	59.9	7.3
			URBAN FRINGE	.000090	21835	2.0	32.7	59.9	7.3
1	39	CHAMPAIGN-URBANA, IL	INNER CITY	.000338	90591	30.6	31.6	61.7	6.7
			URBAN FRINGE	.000106	11189	1.2	31.6	61.7	6.7
1	40	CHARLESTON, SC	INNER CITY	.000273	75355	20.5	16.1	76.3	7.6
			URBAN FRINGE	.000168	181780	30.6	16.1	76.3	7.6
1	41	CHARLESTON, WV	INNER CITY	.000225	76876	17.3	25.0	67.0	8.0
			URBAN FRINGE	.000219	92628	20.3	25.0	67.0	8.0
1	42	CHARLOTTE, NC	INNER CITY	.000270	290078	78.4	19.6	71.4	9.0
			URBAN FRINGE	.000097	46076	4.5	19.6	71.4	9.0

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	43	CHATTANOGA, TENN	INNER CITY	.000145	133613	19.3	18.4	72.9	8.7
			URBAN FRINGE	.000104	115564	12.1	18.4	72.9	8.7
1	44	CHICAGO, IL	INNER CITY	.000904	3742961	3383.1	32.1	62.6	5.3
			URBAN FRINGE	.000264	3062843	809.3	32.1	62.6	5.3
1	45	CINCINNATI, OH	INNER CITY	.000379	454674	172.3	29.4	64.0	6.6
			URBAN FRINGE	.000194	661052	128.5	29.4	64.0	6.6
1	46	CLEVELAND, OH	INNER CITY	.000643	754571	484.9	29.5	64.2	6.2
			URBAN FRINGE	.000177	1214508	215.2	29.5	64.2	6.2
1	47	COLORADO SPRINGS, CO	INNER CITY	.000184	163586	30.2	30.1	61.5	8.3
			URBAN FRINGE	.000181	84507	15.3	30.1	61.5	8.3
1	48	COLUMBIA, MO	INNER CITY	.000080	60342	4.8	26.7	66.2	7.1
1	49	COLUMBIA, SC	INNER CITY	.000209	272201	56.8	15.9	75.2	8.9
1	50	COLUMBUS, GA	INNER CITY	.000144	171757	24.7	18.6	73.8	7.6
			URBAN FRINGE	.000089	60765	5.4	18.6	73.8	7.6
1	51	COLUMBUS, OH	INNER CITY	.000268	541908	145.0	30.8	66.9	2.3
			URBAN FRINGE	.000170	251818	42.7	29.3	63.8	6.8
1	52	CORPUS CHRISTI, TX	INNER CITY	.000135	238677	32.3	13.5	76.8	9.6
			URBAN FRINGE	.000016	9600	.2	13.5	76.8	9.6
1	53	DALLAS, TX	INNER CITY	.000242	984799	238.7	13.4	75.8	10.8
			URBAN FRINGE	.000097	576859	56.2	13.4	76.0	10.6
1	54	DANBURY, CONN	INNER CITY	.000080	52238	4.2	31.8	61.5	6.7
			URBAN FRINGE	.000084	16325	1.4	31.8	61.5	6.7
1	55	DAVENPORT, IOWA	INNER CITY	.000143	199323	28.4	32.7	59.9	7.4
			URBAN FRINGE	.000113	71616	8.1	32.7	59.9	7.4
1	56	DAYTON, OH	INNER CITY	.000383	244601	93.7	29.2	63.5	7.3
			URBAN FRINGE	.000175	444559	77.8	29.2	63.5	7.3
1	57	DECATUR, IL	INNER CITY	.000170	91937	15.6	31.1	60.6	8.4
			URBAN FRINGE	.000066	9110	.6	31.1	60.6	8.4
1	58	DENVER, CO	INNER CITY	.000477	623583	297.3	30.0	61.3	8.7
			URBAN FRINGE	.000256	645337	165.0	30.0	61.3	8.7
1	59	DES MOINES, IOWA	INNER CITY	.000189	205179	38.7	32.6	59.7	7.6
			URBAN FRINGE	.000069	56260	3.9	32.6	59.7	7.6
1	60	DETROIT, MI	INNER CITY	.000839	1559528	1308.5	36.3	57.8	5.9
			URBAN FRINGE	.000316	2537666	802.7	36.3	57.8	5.9
1	61	DUBUQUE, IOWA	INNER CITY	.000188	63681	12.0	33.1	60.5	6.5
			URBAN FRINGE	.000049	3308	.2	33.0	60.5	6.5
1	62	DULUTH MN	INNER CITY	.000092	139525	12.8	39.5	54.1	6.3
			URBAN FRINGE	.000047	5844	.3	39.5	54.1	6.4
1	63	DURHAM, NC	INNER CITY	.000204	114739	23.4	19.4	70.9	9.6
			URBAN FRINGE	.000053	6436	.3	19.4	70.9	9.6

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION		
							HEATING	STATIONARY	MOBILE
I	64	EL PASO,TX	INNER CITY	.000191	393681	75.0	13.7	77.9	8.4
I	65	ERIE,PA	INNER CITY	.000369	129022	47.6	20.4	64.6	7.0
			URBAN FRINGE	.000103	45972	4.7	28.4	64.6	7.0
I	66	EUGENE,OR	INNER CITY	.000226	88243	20.0	25.8	66.1	8.0
			URBAN FRINGE	.000171	72722	12.4	25.8	66.1	8.0
I	67	EVANSVILLE,IN	INNER CITY	.000233	142802	33.3	28.6	63.1	8.3
			URBAN FRINGE	.000036	3898	.1	28.6	63.1	8.3
I	68	FALL RIVER,MASS	INNER CITY	.000155	95190	14.8	30.1	61.8	8.2
			URBAN FRINGE	.000193	41698	8.1	30.1	61.8	8.2
I	69	FARGO,ND	INNER CITY	.000272	87240	23.7	39.0	53.5	7.5
			URBAN FRINGE	.000016	2539	.0	39.0	53.5	7.5
I	70	FAYETTEVILLE,NC	INNER CITY	.000164	64349	10.6	20.1	73.2	6.7
			URBAN FRINGE	.000171	129709	22.2	20.1	73.2	6.7
I	71	FICHBURG,MASS	INNER CITY	.000065	77703	5.1	29.2	63.8	6.9
			URBAN FRINGE	.000013	1803	.0	29.2	63.8	6.9
I	72	FLINT,MI	INNER CITY	.000381	199546	75.9	36.0	57.4	6.6
			URBAN FRINGE	.000152	141108	21.4	36.0	57.4	6.6
I	73	FORT LAUDERDALE,FL	INNER CITY	.000291	315484	92.0	5.3	84.7	10.0
			URBAN FRINGE	.000173	469911	81.5	5.3	84.7	10.0
I	74	FORT SMITH,AR	INNER CITY	.000103	71064	7.3	19.0	69.7	11.2
			URBAN FRINGE	.000055	14387	.8	19.0	69.7	11.2
I	75	FORT WAYNE,IN	INNER CITY	.000216	183007	39.6	28.9	63.7	7.4
			URBAN FRINGE	.000148	48852	7.3	28.9	63.7	7.4
I	76	FORT WORTH,TX	INNER CITY	.000142	458999	65.0	13.4	76.0	10.6
			URBAN FRINGE	.000108	330698	35.9	13.4	76.0	10.6
I	77	FRESNO,CA	INNER CITY	.000250	184271	46.1	15.5	74.2	10.3
			URBAN FRINGE	.000162	107624	17.4	15.5	74.2	10.3
I	78	GADSDEN,AL	INNER CITY	.000089	58294	5.2	10.7	77.9	11.5
			URBAN FRINGE	.000031	14916	.5	10.7	77.9	11.5
I	79	GAINSVILLE,FL	INNER CITY	.000146	82545	12.0	5.3	85.1	9.6
			URBAN FRINGE	.000074	6166	.5	5.3	85.1	9.6
I	80	GALVESTON,TX	INNER CITY	.000148	72104	10.7	13.6	77.3	9.1
I	81	GRAND RAPIDS,MI	INNER CITY	.000296	203832	60.3	35.9	57.2	6.8
			URBAN FRINGE	.000114	160116	18.3	35.9	57.2	6.8
I	82	GREAT FALLS,MT	INNER CITY	.000199	66729	13.3	34.9	56.0	9.1
			URBAN FRINGE	.000066	12008	.8	34.9	56.0	9.2
I	83	GREEN BAY,WI	INNER CITY	.000117	92963	10.9	35.7	58.9	5.4
			URBAN FRINGE	.000063	43914	2.7	35.7	58.9	5.4
I	84	GREENSBORO,NC	INNER CITY	.000217	173465	37.6	19.6	71.4	9.0
			URBAN FRINGE	.000076	9628	.7	19.6	71.4	9.0

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	85	GREENSVILLE,SC	INNER CITY	.000216	68909	14.9	15.9	75.0	9.1
			URBAN FRINGE	.000157	109052	17.1	15.9	75.0	9.1
1	86	HAMILTON,OH	INNER CITY	.000228	67934	15.5	29.2	63.6	7.2
			URBAN FRINGE	.000059	23404	1.4	29.2	63.6	7.2
1	87	HARLINGEN,TX	INNER CITY	.000081	39097	3.2	13.8	78.3	7.9
			URBAN FRINGE	.000074	19777	1.5	13.8	78.3	7.9
1	88	HARRISBURY,PA	INNER CITY	.000430	67776	29.1	28.4	64.6	6.9
			URBAN FRINGE	.000156	172607	26.9	28.4	64.6	6.9
1	89	HARTFORD,CONN	INNER CITY	.000560	162551	91.0	31.8	61.5	6.7
			URBAN FRINGE	.000211	315795	66.5	31.8	61.5	6.7
1	90	HIGH POINT,NC	INNER CITY	.000156	75888	11.8	19.6	71.4	9.0
			URBAN FRINGE	.000104	36608	3.8	19.6	71.4	9.0
1	91	HONOLULU,HAWAII	INNER CITY	.000169	385282	65.0	0.	92.2	7.8
			URBAN FRINGE	.000145	139378	20.3	0.	92.2	7.8
1	92	HOUSTON,TX	INNER CITY	.000229	1437679	329.0	13.5	76.4	10.2
			URBAN FRINGE	.000286	519652	148.8	13.5	76.4	10.2
1	93	HUNTINGTON,WV	INNER CITY	.000383	111346	42.7	25.0	66.8	8.2
			URBAN FRINGE	.000169	68824	11.7	25.0	66.8	8.2
1	94	HUNSVILLE,AL	INNER CITY	.000079	149087	11.8	10.6	77.3	12.1
			URBAN FRINGE	.000030	9393	.3	10.6	77.3	12.1
1	95	INDIANAPOLIS,IN	INNER CITY	.000172	844579	145.3	29.1	64.1	6.8
1	96	JACKSON,MI	INNER CITY	.000239	46931	11.2	35.9	57.2	6.8
			URBAN FRINGE	.000082	34146	2.8	35.9	57.2	6.8
1	97	JACKSON,MS	INNER CITY	.000216	167649	36.2	14.3	76.2	9.6
			URBAN FRINGE	.000134	50187	6.7	14.3	76.2	9.6
1	98	JACKSONVILLE,FL	INNER CITY	.000123	677641	83.2	5.3	85.4	9.3
1	99	JOHNSTOWN,PA	INNER CITY	.000346	42411	14.7	28.4	64.6	7.0
			URBAN FRINGE	.000133	53588	7.1	28.4	64.6	7.0
1	100	JOLIET,IL	INNER CITY	.000250	79712	19.9	31.3	61.1	7.5
			URBAN FRINGE	.000116	77900	9.1	31.3	61.1	7.5
1	101	KALAMAZOO,MI	INNER CITY	.000218	88392	19.3	35.9	57.2	6.8
			URBAN FRINGE	.000093	68540	6.4	35.9	57.2	6.8
1	102	KANSASCITY,MO	INNER CITY	.000138	695752	95.8	26.6	65.8	7.6
			URBAN FRINGE	.000235	439250	103.1	26.6	65.8	7.6
1	103	KENOSHA,WI	INNER CITY	.000280	83562	23.4	35.7	58.9	5.4
			URBAN FRINGE	.000053	5772	.3	35.7	58.9	5.4
1	104	KNOXVILLE,TENN	INNER CITY	.000164	193540	31.8	20.1	71.2	8.7
			URBAN FRINGE	.000098	17642	1.7	20.1	71.2	8.7
1	105	LA CROSSE,WI	INNER CITY	.000166	54232	9.0	35.7	58.8	5.5
			URBAN FRINGE	.000064	12955	.8	35.7	58.8	5.5

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION		
							HEATING	STATIONARY	MOBILE
1	106	LAFAYETTE,LA	INNER CITY	.000190	74990	14.2	9.5	79.4	11.1
			URBAN FRINGE	.000089	10392	.9	9.5	79.4	11.1
1	107	LAFAYETTE,IN	INNER CITY	.000257	46287	11.9	29.2	64.2	6.6
			URBAN FRINGE	.000168	35174	5.9	29.2	64.2	6.6
1	108	LAKE CHARLES,LA	INNER CITY	.000190	84788	16.1	9.5	79.4	11.1
			URBAN FRINGE	.000048	11155	.5	9.5	79.4	11.1
1	109	LANCASTER,PA	INNER CITY	.000382	57501	22.0	28.4	64.7	6.9
			URBAN FRINGE	.000108	59417	6.4	28.4	64.7	6.9
1	110	LANSING,MI	INNER CITY	.000255	135835	34.6	36.0	57.4	6.6
			URBAN FRINGE	.000163	101001	16.5	36.0	57.4	6.6
1	111	LAREDO,TX	INNER CITY	.000176	80419	14.2	14.1	80.1	5.8
			URBAN FRINGE	.000032	1469	.0	14.1	80.1	5.8
1	112	LAS VEGAS,NV	INNER CITY	.000312	168292	52.6	30.1	61.3	8.6
			URBAN FRINGE	.000213	148734	31.7	30.1	61.3	8.6
1	113	LAWRENCE,MASS	INNER CITY	.000133	115153	15.3	29.2	63.8	6.9
			URBAN FRINGE	.000091	88858	8.1	29.2	63.8	6.9
1	114	LAWTON,OK	INNER CITY	.000106	82996	8.8	20.7	68.9	10.4
			URBAN FRINGE	.000066	23421	1.5	20.7	68.9	10.4
1	115	LEWISTON,MAINE	INNER CITY	.000095	46159	4.4	34.9	57.2	7.9
			URBAN FRINGE	.000055	25889	1.4	34.9	57.2	7.9
1	116	LEXINGTON,KY	INNER CITY	.000312	117274	36.6	25.0	66.1	8.8
			URBAN FRINGE	.000193	55744	10.8	25.0	66.1	8.8
1	117	LIMA,OH	INNER CITY	.000240	53733	12.9	28.9	63.0	8.1
			URBAN FRINGE	.000060	16891	1.0	28.9	63.0	8.1
1	118	LINCOLN,NEB	INNER CITY	.000178	158289	28.1	30.8	62.5	6.7
			URBAN FRINGE	.000059	4155	.2	30.8	62.5	6.7
1	119	LITTLE ROCK,AR	INNER CITY	.000223	169189	37.7	19.4	71.2	9.4
			URBAN FRINGE	.000116	82715	9.6	19.4	71.2	9.4
1	120	LORAIN,OH	INNER CITY	.000200	132768	26.6	29.2	63.6	7.2
			URBAN FRINGE	.000059	60399	3.5	29.2	63.6	7.2
1	121	LOS ANGELES,CA	INNER CITY	.000526	4019117	2115.6	15.9	75.8	8.3
			URBAN FRINGE	.000441	5252951	2314.1	15.9	75.8	8.3
1	122	LOUISVILLE,KY	INNER CITY	.000385	372169	143.1	28.9	63.7	7.4
			URBAN FRINGE	.000180	389148	70.2	28.9	63.7	7.4
1	123	LOWELL,MASS	INNER CITY	.000279	96007	26.8	29.2	63.8	6.9
			URBAN FRINGE	.000096	100314	9.6	29.2	63.8	6.9
1	124	LUBBOCK,TX	INNER CITY	.000127	175141	22.2	13.4	76.2	10.3
1	125	LYNCHBURG,VA	INNER CITY	.000128	60505	7.8	21.5	71.0	7.5
			URBAN FRINGE	.000076	18749	1.4	21.5	71.0	7.5
1	126	MACON,GA	INNER CITY	.000156	136452	21.3	18.4	73.0	8.5
			URBAN FRINGE	.000118	6288	.7	18.4	73.0	8.5

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	127	MADISON, WI	INNER CITY	.000203	183672	37.3	35.7	58.9	5.4
			URBAN FRINGE	.000080	34154	2.7	35.7	58.9	5.4
1	128	MANCHESTER, NH	INNER CITY	.000284	100120	28.4	34.8	58.1	7.1
			URBAN FRINGE	.000092	8426	.8	34.8	58.1	7.1
1	129	MANSFIELD, OH	INNER CITY	.000131	55259	7.3	28.9	62.8	8.3
			URBAN FRINGE	.000074	22704	1.7	28.9	62.8	8.3
1	130	MCALLEN, TX	INNER CITY	.000143	43904	6.3	13.7	78.0	8.3
			URBAN FRINGE	.000147	62416	9.2	13.7	78.0	8.3
1	131	MEMPHIS, MS	INNER CITY	.000280	722976	202.1	14.4	77.1	8.4
1	132	MERIDEN, CONN	INNER CITY	.000151	57564	8.7	31.8	61.5	6.7
			URBAN FRINGE	.000063	43714	2.7	31.8	61.5	6.7
1	133	MIAMI, FL	INNER CITY	.000590	428751	253.1	5.4	86.0	8.7
			URBAN FRINGE	.000299	1131901	338.0	5.4	86.6	8.0
1	134	MIDLAND, TX	INNER CITY	.000120	69630	8.3	13.2	75.0	11.8
			URBAN FRINGE	.000011	795	.0	13.2	75.0	11.7
1	135	MILLWAKEE, WI	INNER CITY	.000464	760300	352.7	36.0	59.3	4.7
			URBAN FRINGE	.000107	567564	61.0	36.0	59.3	4.7
1	136	MINNEAPOLIS, MN	INNER CITY	.000503	782074	393.4	39.7	54.4	5.9
			URBAN FRINGE	.000141	1008800	141.9	39.7	54.4	5.9
1	137	MOBILE, AL	INNER CITY	.000101	205432	20.7	10.9	79.3	9.9
			URBAN FRINGE	.000074	73344	5.4	10.9	79.3	9.9
1	138	MODESTO, CA	INNER CITY	.000343	68516	23.5	15.4	73.4	11.2
			URBAN FRINGE	.000108	49289	5.3	15.4	73.4	11.2
1	139	MONROE, LA	INNER CITY	.000142	61282	8.7	9.5	79.4	11.1
			URBAN FRINGE	.000104	37169	3.9	9.5	79.4	11.1
1	140	MONTGOMERY, AL	INNER CITY	.003453	446952	1543.4	11.7	85.0	3.4
			URBAN FRINGE	.000049	5960	.3	10.8	79.1	10.1
1	141	MUNCIE, IN	INNER CITY	.000284	71181	20.2	29.0	63.8	7.2
			URBAN FRINGE	.000091	21926	2.0	29.0	63.8	7.2
1	142	MUSKEGON, MI	INNER CITY	.000197	46054	9.1	36.1	57.5	6.4
			URBAN FRINGE	.000103	63032	6.5	36.1	57.5	6.4
1	143	NASHUA, NH	INNER CITY	.000182	63070	11.5	34.8	58.0	7.2
			URBAN FRINGE	.000150	5865	.9	34.8	58.1	7.1
1	144	NASHVILLE, TENN	INNER CITY	.000114	497128	56.8	20.0	70.9	9.1
1	145	NEW BEDFORD, MASS	INNER CITY	.000220	103655	22.8	29.2	63.8	6.9
			URBAN FRINGE	.000089	32502	2.9	29.2	63.8	6.9
1	146	NEW BRITAIN, CONN	INNER CITY	.000374	85835	32.1	31.8	61.5	6.7
			URBAN FRINGE	.000121	49282	5.9	31.8	61.5	6.7
1	147	NEW HAVEN, CONN	INNER CITY	.000465	141666	65.9	31.8	61.5	6.7
			URBAN FRINGE	.000180	216669	38.9	31.8	61.5	6.7

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	148	NEW ORLEANS, LA	INNER CITY	.000380	1045459	397.2	9.5	79.4	11.1
1	149	NEW YORK, NY	INNER CITY	.001735	8644589	14995.4	32.8	64.7	2.5
			URBAN FRINGE	.000317	7239660	2294.0	32.8	64.7	2.5
1	150	NEWPORT, VA	INNER CITY	.000150	289709	43.4	21.8	71.9	6.3
			URBAN FRINGE	.000028	10412	.3	21.8	71.9	6.3
1	151	NORFORK, VA	INNER CITY	.000349	468664	163.7	21.8	71.9	6.3
			URBAN FRINGE	.000088	278957	24.6	21.8	71.9	6.3
1	152	NORWALK, CONN	INNER CITY	.000229	81464	18.6	31.8	61.5	6.7
			URBAN FRINGE	.000086	28304	2.4	31.8	61.5	6.7
1	153	ODESSA, TX	INNER CITY	.000237	91435	21.6	13.2	74.6	12.3
			URBAN FRINGE	.000024	3808	.1	13.2	74.6	12.3
1	154	OGDEN, UT	INNER CITY	.000253	85166	21.5	30.2	62.0	7.8
			URBAN FRINGE	.000166	98351	16.3	30.2	62.0	7.8
1	155	OKLAHOMA CITY, OK	INNER CITY	.000103	644813	66.2	20.7	68.9	10.4
1	156	OMAHA, IOWA	INNER CITY	.000273	355006	97.0	33.0	60.4	6.7
			URBAN FRINGE	.000116	146544	17.0	33.0	60.4	6.7
1	157	ORLANDO, FL	INNER CITY	.000217	126632	27.4	5.2	83.9	10.8
			URBAN FRINGE	.000141	264249	37.1	5.2	83.9	10.8
1	158	OSHKOSH, KY	INNER CITY	.000267	60167	16.1	24.7	65.2	10.2
1	159	OWENSBORO, KY	INNER CITY	.000349	54568	19.1	24.8	65.7	9.5
			URBAN FRINGE	.000042	3053	.1	24.8	65.7	9.5
1	160	OXNARD, CA	INNER CITY	.000153	180720	27.7	15.8	75.5	8.7
			URBAN FRINGE	.000121	90908	11.0	15.8	75.5	8.7
1	161	PENSACOLA, FL	INNER CITY	.000144	76225	11.0	5.4	85.7	8.9
			URBAN FRINGE	.000158	136975	21.7	5.4	85.7	8.9
1	162	PEORIA, IL	INNER CITY	.000197	128688	25.4	31.3	61.1	7.6
			URBAN FRINGE	.000109	121790	13.2	31.3	61.1	7.6
1	163	PETERSBURG, VA	INNER CITY	.000230	40390	9.3	21.7	71.8	6.5
			URB FRINGE	.000116	72175	8.4	21.7	71.8	6.5
1	164	PHILADELPHIA, PA	INNER CITY	.000929	1997813	1856.6	26.8	66.5	6.7
			URBAN FRINGE	.000248	2124788	527.3	26.8	66.5	6.7
1	165	PHOENIX, ARIZ	INNER CITY	.000289	776670	224.2	10.1	80.0	9.8
			URBAN FRINGE	.000231	376259	86.8	10.1	80.0	9.8
1	166	PINE BLUFF, AR	INNER CITY	.000224	64833	14.6	19.7	72.0	8.3
			URBAN FRINGE	.000040	4087	.2	19.7	72.0	8.3
1	167	PITTSBURG, PA	INNER CITY	.000584	519373	303.3	28.4	64.5	7.1
			URBAN FRINGE	.000201	1323851	266.6	28.4	64.5	7.1
1	168	PITTSFIELD, MASS	INNER CITY	.003703	58188	215.5	29.2	63.8	6.9
			URBAN FRINGE	.000054	5855	.3	29.2	63.8	6.9
1	169	PORT AUTHER, TX	INNER CITY	.000073	66937	4.9	13.5	76.4	10.1
			URBAN FRINGE	.000134	68936	9.3	13.5	76.4	10.1

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	170	PORTLAND, MAINE	INNER CITY	.000223	71942	16.1	34.9	57.2	7.9
			URBAN FRINGE	.000095	45832	4.3	34.9	57.2	7.9
1	171	PORTLAND, OR	INNER CITY	.000340	413242	140.5	29.9	61.0	9.1
			URBAN FRINGE	.000215	479439	103.2	29.9	61.0	9.1
1	172	PROVIDENCE, RI	INNER CITY	.000314	333723	104.8	30.1	61.8	8.2
			URBAN FRINGE	.000163	447310	73.1	30.1	61.8	8.2
1	173	PROVO, UT	INNER CITY	.000177	96684	17.1	30.3	62.3	7.4
			URBAN FRINGE	.000069	30921	2.1	30.3	62.3	7.4
1	174	PUEBLO, CO	INNER CITY	.000319	118074	37.7	30.0	61.2	8.9
			URBAN FRINGE	.000041	7084	.3	30.0	61.2	8.9
1	175	RACINE, WI	INNER CITY	.000350	100924	35.4	35.8	59.0	5.2
			URBAN FRINGE	.000073	23552	1.7	35.8	59.0	5.2
1	176	RALEIGH, NC	INNER CITY	.000217	145665	31.6	19.4	70.9	9.6
			URBAN FRINGE	.000090	37473	3.4	19.4	70.9	9.6
1	177	READING, PA	INNER CITY	.000437	87487	38.2	28.4	64.6	7.0
			URBAN FRINGE	.000149	80188	11.9	28.4	64.6	7.0
1	178	RENO, NEV	INNER CITY	.000293	97597	28.6	29.7	60.5	9.9
			URBAN FRINGE	.000357	35929	12.8	29.7	60.5	9.9
1	179	RICHMOND, VA	INNER CITY	.000274	279266	76.6	21.5	71.1	7.4
			URBAN FRINGE	.000135	186768	25.3	21.5	71.1	7.4
1	180	ROANOKE, VA	INNER CITY	.000209	103054	21.6	21.3	70.4	8.3
			URBAN FRINGE	.000104	72166	7.5	21.3	70.4	8.3
1	181	ROCHESTER, MN	INNER CITY	.000225	56493	12.7	39.5	54.1	6.4
			URBAN FRINGE	.000076	2981	.2	39.5	54.1	6.4
1	182	ROCHESTER, NY	INNER CITY	.000446	290336	129.5	31.7	62.6	5.7
			URBAN FRINGE	.000177	299054	52.9	31.7	62.6	5.7
1	183	ROCKFORD, IL	INNER CITY	.000247	149204	36.8	31.5	61.4	7.2
			URBAN FRINGE	.000122	59678	7.3	31.5	61.4	7.2
1	184	SACRAMENTO, CA	INNER CITY	.000187	282409	52.9	15.7	74.8	9.5
			URBAN FRINGE	.000185	421196	77.9	15.7	74.8	9.5
1	185	SAGINAW, MI	INNER CITY	.000316	94747	29.9	36.1	57.5	6.4
			URBAN FRINGE	.000131	57509	7.5	36.1	57.5	6.4
1	186	ST. JOSEPH, MO	INNER CITY	.000141	75187	10.6	26.5	65.6	7.9
			URBAN FRINGE	.000054	4363	.2	26.5	65.6	7.9
1	187	ST. LOUIS, MO	INNER CITY	.000610	640994	391.1	26.9	66.6	6.5
			URBAN FRINGE	.000239	1298715	310.7	26.9	66.6	6.5
1	188	ST. PETERSBURG, FL	INNER CITY	.000253	276472	69.9	5.3	85.0	9.7
			URBAN FRINGE	.000186	357117	66.4	5.3	85.0	9.7
1	189	SALEM, OR	INNER CITY	.000213	78889	16.8	25.8	66.2	8.0
			URBAN FRINGE	.000141	28657	4.0	25.8	66.2	8.0

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	190	SALINAS,CA	INNER CITY	.000237	65389	15.5	15.8	75.6	8.6
			URBAN FRINGE	.000087	3952	.3	15.8	75.6	8.6
1	191	SALT LAKE CITY,UT	INNER CITY	.000258	215491	55.5	30.2	62.0	7.8
			URBAN FRINGE	.000232	372030	86.3	30.2	62.0	7.8
1	192	SANANGELO,TX	INNER CITY	.000112	74524	8.4	13.2	75.0	11.7
1	193	SAN ANTONIO,TX	INNER CITY	.000254	763268	193.6	13.7	77.5	8.8
			URBAN FRINGE	.000178	137915	24.6	13.7	77.5	6.8
1	194	SAN BERNARDINO,CA	INNER CITY	.000151	271084	41.0	15.5	73.9	10.7
			URBAN FRINGE	.000134	376859	50.5	15.5	73.9	10.7
1	195	SAN DIEGO,CA	INNER CITY	.000175	773368	135.3	15.8	75.6	8.6
			URBAN FRINGE	.000511	557080	284.7	15.8	75.6	8.6
1	196	SAN FRANCISCO,CA	INNER CITY	.000700	1269817	889.0	15.9	75.9	8.2
			URBAN FRINGE	.000277	2047469	567.9	15.9	75.9	8.2
1	197	SAN JOSE,CA	INNER CITY	.000236	495735	116.9	15.8	75.4	8.8
			URBAN FRINGE	.000296	642583	190.3	15.8	75.4	8.8
1	198	SANTA BARBARA,CA	INNER CITY	.000190	77952	14.8	15.8	75.4	8.8
			URBAN FRINGE	.000205	66130	13.5	15.8	75.4	8.8
1	199	SANTA ROSA,CA	INNER CITY	.000144	55371	8.0	15.4	73.6	11.0
			URBAN FRINGE	.000080	27989	2.2	15.4	73.6	11.0
1	200	SAVANNAH,CA	INNER CITY	.000253	131905	33.4	18.5	73.5	8.0
			URBAN FRINGE	.000074	50612	3.7	18.5	73.5	8.0
1	201	SCRANTON,PA	INNER CITY	.000230	103336	23.8	27.9	63.4	8.8
			URBAN FRINGE	.000091	100557	9.1	27.9	63.4	8.8
1	202	SEASIDE,CA	INNER CITY	.000203	69114	14.1	15.8	75.6	8.6
			URBAN FRINGE	.000217	34454	7.5	15.8	75.6	8.6
1	203	SEATTLE,WA	INNER CITY	.000420	632640	265.6	30.1	61.4	8.5
			URBAN FRINGE	.000200	707159	141.2	30.1	61.4	8.5
1	204	SHERMAN,TX	INNER CITY	.000085	33922	2.9	13.1	74.2	12.7
			URBAN FRINGE	.000091	30638	2.8	13.1	74.2	12.7
1	205	SHREVEPORT,LA	INNER CITY	.000201	198150	39.8	9.5	79.4	11.1
			URBAN FRINGE	.000084	56836	4.8	9.5	79.4	11.1
1	206	SIMI VALLEY,CA	INNER CITY	.000142	62925	8.9	15.8	75.5	8.7
			URBAN FRINGE	.000006	288	.0	15.8	75.5	8.7
1	207	SIOUX CITY,IOWA	INNER CITY	.000096	87811	8.4	32.6	59.6	7.8
			URBAN FRINGE	.000058	10231	.6	32.6	59.6	7.8
1	208	SIOUX FALLS,SD	INNER CITY	.000213	7530	1.6	20.8	32.6	46.7
			URBAN FRINGE	.000055	2761	.2	35.8	56.1	8.0
1	209	SOUTH BEND,IN	INNER CITY	.000250	129531	32.4	29.1	64.0	6.9
			URBAN FRINGE	.000144	167596	24.1	29.1	64.0	6.9
1	210	SPOKANE,WA	INNER CITY	.000249	184521	45.9	29.8	60.9	9.4
			URBAN FRINGE	.000149	63958	9.5	29.8	60.9	9.4

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	211	SPRINGFIELD, IL	INNER CITY	.000202	92851	18.8	31.2	60.8	8.0
			URBAN FRINGE	.000162	29583	4.8	31.2	60.8	8.0
1	212	SPRINGFIELD, MO	INNER CITY	.000120	123616	14.9	26.2	64.8	9.0
			URBAN FRINGE	.000035	1301	.0	26.2	64.8	9.0
1	213	SPRINGFIELD, OH	INNER CITY	.000267	82234	22.0	29.1	63.3	7.6
			URBAN FRINGE	.000071	11858	.8	29.1	63.3	7.6
1	214	SPRINGFIELD, MASS	INNER CITY	.000165	285822	47.2	29.2	63.8	6.9
			URBAN FRINGE	.000084	238068	20.0	29.2	63.8	6.9
1	215	STAMFORD, CONN	INNER CITY	.000194	111976	21.8	31.8	61.5	6.7
			URBAN FRINGE	.000159	78227	12.4	31.8	61.5	6.7
1	216	STEUBENVILLE, OH	INNER CITY	.000123	58300	7.1	29.3	63.8	6.8
			URBAN FRINGE	.000121	27592	3.3	29.3	63.8	6.8
1	217	STOCKTON, CA	INNER CITY	.000217	119307	25.9	15.5	74.3	10.2
			URBAN FRINGE	.000174	58748	10.2	15.5	74.3	10.2
1	218	SYRACUSE, NY	INNER CITY	.000404	193343	78.2	31.7	62.6	5.7
			URBAN FRINGE	.000153	175338	26.8	31.7	62.6	5.7
1	219	TACOMA, WA	INNER CITY	.000236	167249	39.5	30.1	61.5	8.5
			URBAN FRINGE	.000170	192583	32.8	30.1	61.5	8.5
1	220	TALLAHASSEE, FL	INNER CITY	.000161	92044	14.8	5.4	85.9	8.7
			URBAN FRINGE	.000070	7573	.5	5.4	85.9	8.7
1	221	TAMPA, FL	INNER CITY	.000225	355382	79.9	5.3	85.0	9.7
			URBAN FRINGE	.000124	116448	14.5	5.3	85.0	9.7
1	222	TERRE HAUTE, IN	INNER CITY	.000156	72400	11.3	28.8	63.3	7.9
			URBAN FRINGE	.000086	10906	.9	28.8	63.3	7.9
1	223	TEXARKANA, TX	INNER CITY	.000102	35576	3.6	13.3	75.3	11.4
			URBAN FRINGE	.000102	32748	3.3	13.3	75.3	11.4
1	224	TEXAS CITY, TX	INNER CITY	.000066	98054	6.4	13.6	77.3	9.1
1	225	TOLEDO, OH	INNER CITY	.000342	396260	135.7	36.0	57.3	6.8
			URBAN FRINGE	.000089	107083	9.5	36.0	57.3	6.8
1	226	TOPEKA, KANS	INNER CITY	.000124	129830	16.2	25.0	65.4	9.6
			URBAN FRINGE	.000047	7450	.4	25.0	65.4	9.6
1	227	TRENTON, NJ	INNER CITY	.000599	107218	64.2	26.8	66.6	6.6
			URBAN FRINGE	.000163	173851	28.4	26.8	66.6	6.6
1	228	TUCSON, ARIZ	INNER CITY	.000351	351121	123.2	10.1	80.1	9.7
			URBAN FRINGE	.000115	41732	4.8	10.1	80.1	9.7
1	229	TULSA, OK	INNER CITY	.000107	369012	39.3	20.7	68.7	10.6
			URBAN FRINGE	.000187	44151	8.2	20.7	68.7	10.6
1	230	TUSCALOOSA, AL	INNER CITY	.000123	71120	8.7	10.9	79.7	9.3
			URBAN FRINGE	.000058	21736	1.3	10.9	79.7	9.3
1	231	TYLER, TX	INNER CITY	.000141	67392	9.5	13.3	75.4	11.3
			URBAN FRINGE	.000044	2345	.1	13.3	75.4	11.3

TABLE 33 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION		
							HEATING	STATIONARY	MOBILE
1	232	UTICA, NY	INNER CITY	.000285	89829	25.6	31.8	62.8	5.4
			URBAN FRINGE	.000088	86935	7.6	31.8	62.8	5.4
1	233	VINELAND, NJ	INNER CITY	.000039	48846	1.9	26.8	66.6	6.6
			URBAN FRINGE	.000079	26590	2.1	26.8	66.6	6.6
1	234	WACO, TX	INNER CITY	.000103	111203	11.4	13.4	75.9	10.7
			URBAN FRINGE	.000044	27434	1.2	13.4	75.9	10.7
1	235	WASHINGTON, DC	INNER CITY	.000643	679565	436.7	24.4	71.1	4.5
			URBAN FRINGE	.000265	1549513	410.5	24.4	71.1	4.5
1	236	WATERBURY, CONN	INNER CITY	.000256	111132	28.4	31.8	61.5	6.7
			URBAN FRINGE	.000101	50357	5.1	31.8	61.5	6.7
1	237	WATERLOO, IOWA	INNER CITY	.000075	77237	5.8	32.7	59.8	7.5
			URBAN FRINGE	.000179	38121	6.8	32.7	59.8	7.5
1	238	WEST PALM BEACH, FL	INNER CITY	.000093	73355	6.8	5.3	84.7	10.0
			URBAN FRINGE	.000165	294599	48.6	5.3	84.7	10.0
1	239	WHEELING, WV	INNER CITY	.000282	51906	14.6	25.2	67.5	7.2
			URBAN FRINGE	.000239	48018	11.5	25.2	67.5	7.2
1	240	WICHITA, KANS	INNER CITY	.000164	287535	47.0	24.9	65.2	9.9
			URBAN FRINGE	.000058	26638	1.6	24.9	65.2	9.9
1	241	WICHITA FALLS, TX	INNER CITY	.000142	113814	16.1	13.3	75.4	11.3
1	242	WILKES, PA	INNER CITY	.000424	58727	24.9	27.9	63.4	8.8
			URBAN FRINGE	.000141	163762	23.0	27.9	63.4	8.8
1	243	WILMINGTON, DEL	INNER CITY	.000352	86106	30.3	26.5	65.8	7.7
			URBAN FRINGE	.000218	311582	67.9	26.5	65.8	7.7
1	244	WILMINGTON, NC	INNER CITY	.000187	55521	10.4	19.6	71.5	8.8
			URBAN FRINGE	.000067	13800	.9	19.6	71.5	8.8
1	245	WINSTON, NC	INNER CITY	.000193	159823	30.8	19.6	71.4	9.0
			URBAN FRINGE	.000067	11644	.8	19.6	71.4	9.0
1	246	WORCESTER, MASS	INNER CITY	.000216	179893	38.8	29.2	63.8	6.9
			URBAN FRINGE	.000071	72132	5.2	29.2	63.8	6.9
1	247	YORK, PA	INNER CITY	.000437	50278	22.0	28.4	64.6	6.9
			URBAN FRINGE	.000132	72659	9.6	28.4	64.6	6.9
1	248	YOUNGSTOWN, OH	INNER CITY	.000274	204127	56.0	29.2	63.6	7.1
			URBAN FRINGE	.000153	193268	29.6	29.2	63.6	7.1

Source: Systems Applications, Incorporated computations.

TABLE 34. BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS IN TYPE II CITIES

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION		
						HEATING	STATIONARY	MOBILE
2	1	ANNISTON, AL	.000095	34069	3.2	10.8	78.9	10.3
2	2	BESSEMER, AL	.000110	36206	4.0	10.9	79.5	9.6
2	3	DECATUR, AL	.000075	41137	3.1	10.6	77.5	11.8
2	4	DOTHAN, AL	.000042	39719	1.7	10.6	77.5	11.8
2	5	FLORENCE, AL	.000089	58294	5.2	10.7	77.8	11.6
2	6	PHENIX CITY, AL	.000064	27336	1.8	10.6	77.5	11.8
2	7	SELMA, AL	.000100	29604	3.0	10.6	77.5	11.8
2	8	ANCHORAGE, AL	.000306	67419	20.6	39.1	53.3	7.7
2	9	FLAGSTAFF, AR	.000042	34876	1.5	10.2	80.4	9.4
2	10	YUMA, AR	.000292	38736	11.3	10.2	80.4	9.4
2	11	EL DORADO, AR	.000102	28609	2.9	19.1	70.1	10.8
2	12	FAYETTEVILLE, AR	.000111	34670	3.9	19.2	70.2	10.6
2	13	HOTSPRING, AR	.000103	40318	4.2	19.1	70.1	10.8
2	14	JONESBORO, AR	.000141	30581	4.3	19.1	70.1	10.8
2	15	WEST MEMPHIS, AR	.000179	29340	5.2	19.1	70.1	10.8
2	16	ANTIOCH, CA	.000189	31092	5.9	15.8	75.5	8.7
2	17	CONCORD, CA	.000192	94446	18.1	15.8	75.5	8.7
2	18	CORONA, CA	.000069	30538	2.1	15.7	75.0	9.4
2	19	FAIRFIELD, CA	.000156	49013	7.6	15.8	75.8	8.4
2	20	LANCASTER, CA	.000121	36161	4.4	15.9	75.8	8.3
2	21	LIVERMORE, CA	.000167	41860	7.0	15.9	75.9	8.2
2	22	LODI, CA	.000204	31854	6.5	15.5	74.3	10.2
2	23	LOMPAC, CA	.000132	28111	3.7	15.8	75.4	8.8
2	24	NAPA, CA	.000149	39944	6.0	15.6	74.5	10.0
2	25	NEWARK, CA	.000163	30144	4.9	15.9	75.9	8.2
2	26	NOVATO, CA	.000085	34232	2.9	15.8	75.7	8.5
2	27	OCEANSIDE, CA	.000070	44955	3.1	15.8	75.6	8.6
2	28	REDLANDS, CA	.000098	40428	4.0	15.3	73.1	11.6
2	29	REDWOOD CITY, CA	.000154	61662	9.5	15.7	75.1	9.2
2	30	SAN LUIS OBISPO, CA	.000159	31127	5.0	15.6	74.8	9.6
2	31	SAN RAFAEL, CA	.000147	43243	6.4	15.8	75.7	8.5
2	32	SANTA CRUZ, CA	.000142	35612	5.1	15.5	73.9	10.6
2	33	SANTA MARIA, CA	.000124	36359	4.5	15.8	75.4	8.8
2	34	VISALIA, CA	.000118	30274	3.6	15.6	74.8	9.5
2	35	WALNUT CREEK, CA	.000147	44224	6.5	15.8	75.5	8.7
2	36	FORT COLLINS, CO	.000274	52544	14.4	29.6	60.4	10.1
2	37	GREELEY, CO	.000330	47133	15.6	29.6	60.4	10.1
2	38	MIDDLETOWN, CON	.000058	37961	2.2	31.8	61.5	6.7
2	39	MILFORD, CON	.000145	52317	7.6	31.8	61.5	6.7
2	40	NEW LONDON, CON	.000280	32512	9.1	31.8	61.5	6.7

TABLE 34 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
2	41	NORWICH, CON	.000103	42621	4.4	31.8	61.5	6.7
2	42	SHELTON, CON	.000059	27974	1.7	31.8	61.5	6.7
2	43	TORRINGTON, CON	.000055	32868	1.8	31.8	61.5	6.7
2	44	DAYTONA BEACH, FL	.000113	57999	6.5	5.4	87.1	7.5
2	45	FORTMYERS, FL	.000124	34997	4.3	5.2	83.9	10.9
2	46	FORT PIERCE, FL	.000147	38039	5.6	5.4	85.8	8.8
2	47	KEY WEST, FL	.000313	34961	10.9	5.3	84.9	9.8
2	48	LAKELAND, FL	.000180	53166	9.6	5.2	83.7	11.0
2	49	MELBOURNE, FL	.000092	51582	4.7	5.3	85.2	9.5
2	50	MERRITT ISLAND, FL	.000100	37405	3.7	5.3	85.2	9.5
2	51	PANAMA CITY, FL	.000127	41106	5.2	5.3	84.9	9.8
2	52	POMPANO BEACH, FL	.000175	48253	8.5	5.3	84.7	10.0
2	53	SARASOTA, FL	.000160	51486	8.2	5.2	83.3	11.5
2	54	TITUSVILLE, FL	.000111	39046	4.3	5.3	85.2	9.5
2	55	ATHENS, GE	.000165	49423	8.1	18.2	72.1	9.7
2	56	ROME, GE	.000123	34280	4.2	18.2	72.1	9.7
2	57	VALDOSTA, GE	.000154	36226	5.6	18.2	72.1	9.7
2	58	WARNER ROBINS, GE	.000117	37260	4.4	18.4	72.8	8.8
2	59	HILO, HA	.000020	31260	.6	0.	91.5	8.5
2	60	IDAHO FALLS, ID	.000264	44055	11.6	28.5	59.9	11.6
2	61	LEWISTON, ID	.000127	32100	4.1	28.4	59.8	11.8
2	62	POCATELLO, ID	.000213	49300	10.5	28.5	59.9	11.6
2	63	ALTON, IL	.000180	40239	7.2	31.3	61.1	7.5
2	64	BELLEVILLE, IL	.000214	42477	9.1	31.3	61.1	7.5
2	65	DANVILLE, IL	.000168	43270	7.3	31.3	61.1	7.5
2	66	DE KALB, IL	.000417	33375	13.9	31.3	61.1	7.5
2	67	EAST ST. LOUIS, IL	.000259	70897	18.3	31.3	61.1	7.5
2	68	FREEPORT, IL	.000161	28112	4.5	31.3	61.1	7.5
2	69	GALESBURG, IL	.000150	36783	5.5	31.3	61.1	7.5
2	70	KANKAKEE, IL	.000194	31305	6.1	31.3	61.1	7.5
2	71	PEKIN, IL	.000167	31722	5.3	31.5	61.3	7.2
2	72	QUINCY, IL	.000192	45903	8.8	31.3	61.1	7.5
2	73	BLOOMINGTON, IN	.000258	44044	11.4	28.5	62.7	8.9
2	74	COLUMBUS, IN	.000160	28104	4.5	28.5	62.7	8.9
2	75	ELKHART, IN	.000153	44886	6.9	28.5	62.7	8.9
2	76	KOKOMO, IN	.000246	45347	11.1	28.5	62.7	8.9
2	77	MARION, IN	.000214	41017	8.8	28.5	62.7	8.9
2	78	MICHIGAN, IN	.000108	40437	4.4	28.5	62.7	8.9
2	79	NEW ALBANY, IN	.000179	39540	7.1	28.5	62.7	8.9
2	80	RICHMOND, IN	.000173	45314	7.9	28.5	62.7	8.9

TABLE 34 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	PERCENTAGE OF CONTRIBUTION STATIONARY	PERCENTAGE OF CONTRIBUTION MOBILE
2	81	AMES, IA	.000122	40570	5.0	31.8	58.1	10.1
2	82	BURLINGTON, IA	.000125	33156	4.1	31.8	58.1	10.1
2	83	CLINTON, IA	.000059	35481	2.1	31.8	58.1	10.1
2	84	FORT DODGE, IA	.000110	31949	3.5	31.8	58.1	10.1
2	85	IOWA CITY, IA	.000118	47878	5.7	31.8	58.1	10.1
2	86	MARSHALLTOWN, IA	.000092	26944	2.5	31.8	58.1	10.1
2	87	MASON CITY, IA	.000103	31160	3.2	31.8	58.1	10.1
2	88	OTTUMIVA, IA	.000124	30346	3.8	31.8	58.1	10.1
2	89	HUTCHINSON, KA	.000114	38329	4.4	24.3	63.6	12.1
2	90	LAWRENCE, KA	.000116	47365	5.5	24.3	63.6	12.1
2	91	LEAVENWORTH, KA	.000111	26131	2.9	24.3	63.6	12.1
2	92	MANHATTAN, KA	.000143	28634	4.1	24.3	63.6	12.1
2	93	OVERLAND PARK, KA	.000081	79878	6.4	24.3	63.6	12.1
2	94	PRAIRIE VILLAGE, KA	.000168	29204	4.9	24.3	63.6	12.1
2	95	SALINA, KA	.000101	39191	4.0	24.3	63.6	12.1
2	96	BOWLING GREEN, KE	.000144	39316	5.7	24.7	65.2	10.2
2	97	FORT KNOX, KE	.000123	40670	5.0	24.7	65.2	10.2
2	98	PADUCAH, KE	.000165	34299	5.7	24.7	65.2	10.2
2	99	ALEXANDRIA, LA	.000179	45120	8.1	9.5	79.4	11.1
2	100	BOSSIER CITY, LA	.000110	45384	5.0	9.5	79.4	11.1
2	101	HOUMA, LA	.000180	33582	6.0	9.5	79.4	11.1
2	102	KENNER, LA	.000111	32514	3.6	9.5	79.4	11.1
2	103	NEW IBERIA, LA	.000196	32771	6.4	9.5	79.4	11.1
2	104	BANGOR, ME	.000076	36645	2.8	34.9	57.2	7.9
2	105	ANNAPOLIS, MD	.000247	31448	7.8	25.7	66.9	7.4
2	106	CUMBERLAND, MD	.000188	31690	6.0	25.7	66.7	7.7
2	107	HAGERSTOWN, MD	.000215	38111	8.2	25.7	66.7	7.7
2	108	ATTLEBORO, MASS	.000054	33520	1.8	29.2	63.8	6.9
2	109	GLOUCESTER, MASS	.000049	28457	1.4	29.2	63.8	6.9
2	110	MARLBOROUGH, MASS	.000058	28456	1.6	29.2	63.8	6.9
2	111	TAUNTON, MASS	.000044	44571	2.0	29.2	63.8	6.9
2	112	BATTLECREEK, MICH	.000188	40172	7.6	35.8	57.1	7.1
2	113	HOLLAND, MICH	.000111	27176	3.0	35.8	57.0	7.3
2	114	MIDLAND, MICH	.000089	36328	3.2	35.8	57.0	7.3
2	115	PORT HURON, MICH	.000256	36971	9.5	36.0	57.4	6.6
2	116	YPSILANTI, MICH	.000356	30442	10.8	36.2	57.7	6.1
2	117	AUSTIN, MN	.000182	26300	4.8	38.7	53.1	8.2
2	118	MANKATO, MN	.000173	32462	5.6	38.7	53.1	8.2
2	119	ST. CLOUD, MN	.000201	41704	8.4	39.4	54.0	6.6
2	120	WINONA, MN	.000116	27721	3.2	38.7	53.1	8.2

TABLE 34 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
2	121	COLUMBUS,MI	.000177	28087	5.0	14.1	75.4	10.4
2	122	GREENVILLE,MI	.000280	43171	12.1	14.1	75.4	10.4
2	123	HATTIESBURG,MI	.000136	41674	5.7	14.1	75.4	10.4
2	124	MERIDIAN,MI	.000116	49089	5.7	14.1	75.4	10.4
2	125	PASCAGOULA,MI	.000113	29912	3.4	14.1	75.4	10.4
2	126	VISKSBURG,MI	.000143	27859	4.0	14.1	75.4	10.4
2	127	CAPE GIRARDEAU,MO	.000088	31850	2.8	26.3	65.1	8.7
2	128	FERGUSON,MO	.000222	29706	6.6	26.9	66.6	6.6
2	129	FLORISSANT,MO	.000346	67995	23.6	26.9	66.6	6.6
2	130	FORT LEONARDWOOD,MO	.000139	34868	4.9	26.3	65.1	8.7
2	131	JEFFERSON CITY,MO	.000091	33222	3.0	26.3	65.1	8.7
2	132	JOPLIN,MO	.000076	40409	3.1	26.3	65.1	8.7
2	133	KIRKWOOD,MO	.000169	32841	5.5	26.9	66.6	6.6
2	134	RAYTOWN,MO	.000162	34649	5.6	26.8	66.4	6.9
2	135	ST. CHARLES,MO	.000162	32793	5.3	26.4	65.4	8.2
2	136	MISSOULA,MT	.000175	32651	5.7	33.5	53.7	12.8
2	137	GRAND ISLAND,NE	.060143	33103	4.7	29.5	59.8	10.7
2	138	CONCARD,NH	.000054	34252	1.8	34.8	58.1	7.1
2	139	PORTSMOUTH,NH	.000163	29878	4.9	34.8	58.1	7.1
2	140	LONG BRANCH,NJ	.000255	32576	8.3	26.8	66.6	6.6
2	141	NEW BRUNSWICK,NJ	.000309	42911	13.3	26.8	66.6	6.6
2	142	OLD BRIDGE,NJ	.000175	25811	4.5	26.8	66.6	6.6
2	143	PERTH AMBOY,NJ	.000334	39756	13.3	26.8	66.6	6.6
2	144	SAYREVILLE,NJ	.000095	33328	3.2	26.8	66.6	6.6
2	145	CLOUIS NM	.000158	34117	5.4	22.9	65.5	11.6
2	146	HOBBS,NM	.000104	31197	3.2	22.9	65.5	11.6
2	147	LAS CRUCES,NM	.000142	45234	6.4	22.9	65.5	11.6
2	148	ROSWELL,NM	.000097	40316	3.9	22.9	65.5	11.6
2	149	SANTA FE,NM	.000099	49189	4.9	22.9	65.5	11.6
2	150	AMSTERDAM,NY	.000193	25015	4.8	31.7	62.6	5.6
2	151	AUBURN,NY	.000186	33910	6.3	32.0	63.2	4.8
2	152	ELMIRA,NY	.000247	39149	9.7	31.7	62.6	5.7
2	153	ITHACA,NY	.000203	25703	5.2	32.0	63.2	4.8
2	154	JAMESTOWN,NY	.000194	39002	7.6	32.0	63.2	4.8
2	155	KINGSTON,NY	.000149	25035	3.7	32.0	63.2	4.8
2	156	NEWBURGH,NY	.000278	25697	7.1	32.0	63.2	4.8
2	157	NIGARA FALLS,NY	.000310	83910	26.0	31.8	62.8	5.4
2	158	NORTH TONARVANDA,NY	.000169	35295	6.0	31.8	62.8	5.4
2	159	POUGHKEEPSIE,NY	.000295	32371	9.5	31.8	62.7	5.6
2	160	WATERTOWN,NY	.000154	30174	4.7	32.0	63.2	4.8

TABLE 34 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION		
						HEATING	STATIONARY	MOBILE
2	161	BURLINGTON, NC	.000166	43330	7.2	19.5	71.3	9.2
2	162	CAMP LEJUNE CENTRAL	.000150	41509	6.2	19.4	70.6	10.0
2	163	CHAPEL HILL, NC	.000212	30714	6.5	19.3	70.6	10.1
2	164	CASTTONIA, NC	.000169	56704	9.6	19.7	71.9	8.4
2	165	GOLDSBORA, NC	.000197	32254	6.3	19.4	70.6	10.0
2	166	GREENVILLE, NC	.000173	34968	6.1	19.4	70.6	10.0
2	167	KANNAPOLIS, NC	.000093	43576	4.0	19.4	70.6	10.0
2	168	ROCKY MOUNT, NC	.000190	41266	7.8	19.4	70.6	10.0
2	169	WILSON, NC	.000236	35291	8.3	19.4	70.6	10.0
2	170	BISMARCK, ND	.000197	36970	7.3	37.5	50.9	11.7
2	171	GRAND FORKS, ND	.000257	41634	10.7	37.5	50.9	11.7
2	172	MINOT, ND	.000237	34410	8.2	37.5	50.9	11.7
2	173	ALLIANCE, OH	.000204	26671	5.5	29.4	63.9	6.7
2	174	AUSTINTOWN, OH	.000177	29500	5.2	29.4	63.9	6.7
2	175	BOARDMAN, OH	.000164	31004	5.1	29.4	63.9	6.7
2	176	FAIRBORN, OH	.000213	32430	6.9	29.0	63.0	8.0
2	177	FINDLAY, OH	.000162	35968	5.8	29.4	63.9	6.7
2	178	LANCASTER, OH	.000135	33065	4.5	28.7	62.5	8.7
2	179	MARION, OH	.000268	38862	10.4	29.0	63.0	8.0
2	180	MASSILON, OH	.000186	32753	6.1	29.0	63.0	8.0
2	181	NEWARK, OH	.000169	42018	7.1	28.6	62.3	9.1
2	182	PORTSMOUTH, OH	.000119	27762	3.3	29.0	63.0	8.0
2	183	SANDUSKY, OH	.000182	32827	6.0	29.0	63.0	8.0
2	184	XENIA, OH	.000204	25492	5.2	29.0	63.0	8.0
2	185	ZANESVILLE, OH	.000204	33200	6.8	29.0	63.0	8.0
2	186	BARLESVILLE, OK	.000134	32999	4.4	18.9	62.9	18.1
2	187	ENID, OK	.000083	49544	4.1	20.2	67.3	12.5
2	188	MUSKOGEE, OK	.000073	41517	3.0	20.2	67.3	12.5
2	189	PONCA, OK	.000057	28849	1.7	20.9	69.6	9.5
2	190	SHAWNE, OK	.000035	27949	1.0	20.4	67.7	11.9
2	191	STILLWATER, OK	.000076	34616	2.6	20.2	67.3	12.5
2	192	CORVALLIS, OR	.000301	40633	12.2	25.4	65.2	9.3
2	193	MEDFORD, OR	.000166	32890	5.5	25.4	65.2	9.3
2	194	LEBANON, PA	.000286	28528	8.2	27.9	63.4	8.8
2	195	NEW CASTLE, PA	.000246	38500	9.5	27.9	63.4	8.8
2	196	STATE COLLEGE, PA	.000359	33726	12.1	27.9	63.4	8.8
2	197	WILLIAMSPORT, PA	.000205	37860	7.8	28.4	64.6	7.0
2	198	NEWPORT, RI	.000207	33941	7.0	30.1	61.8	8.2
2	199	WOONSOCKET, RI	.000262	45979	12.0	30.1	61.8	8.2
2	200	ANDERSON, SC	.000172	31023	5.3	15.8	74.9	9.3

TABLE 34 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION		
						HEATING	STATIONARY	MOBILE
2	201	FLORENCE,SC	.000177	29267	5.2	15.8	74.9	9.3
2	202	ROCK HILL,SC	.000167	38104	6.4	15.8	74.9	9.3
2	203	SPARTANBURG,SC	.000192	50150	9.6	16.0	75.7	8.3
2	204	ABERDEEN,SD	.000230	27509	6.3	34.6	54.2	11.2
2	205	RAPID CITY,SD	.000148	45547	6.7	34.6	54.2	11.2
2	206	CLARKSVILLE,TN	.000077	35162	2.7	20.3	71.9	7.8
2	207	JACKSON,TN	.000141	44338	6.3	19.7	69.9	10.4
2	208	JOHNSON CITY,TN	.000128	37436	4.8	20.1	71.1	8.8
2	209	KINGSPORT,TN	.000110	35385	3.9	20.2	71.6	8.2
2	210	MURFREESBORO,TN	.000132	29221	3.9	19.9	70.6	9.4
2	211	OAK RIDGE,TN	.000026	31465	.8	19.6	69.6	10.8
2	212	BIG SPRING,TX	.000119	33624	4.0	13.2	74.8	12.0
2	213	DENTON,TX	.000083	46515	3.9	13.3	75.7	11.0
2	214	FORT HOOD,TX	.000192	38119	7.3	13.7	77.6	8.7
2	215	KILLEEN,TX	.000076	41421	3.2	13.7	77.6	8.7
2	216	KINGSVILLE,TX	.000137	33369	4.6	13.2	74.8	12.0
2	217	LONGVIEW,TX	.000115	53171	6.1	13.2	74.8	12.0
2	218	MEXQUITE,TX	.000121	64404	7.8	13.5	76.4	10.2
2	219	RICHARDSON,TX	.000100	56767	5.7	13.3	75.6	11.1
2	220	TEMPLE,TX	.000081	38999	3.2	13.7	77.6	8.7
2	221	VICTORIA,TX	.000136	48236	6.6	13.2	74.8	12.0
2	222	BURLINGTON,VT	.000260	42548	11.1	36.2	56.4	7.5
2	223	CHARLOTTESVILLE,VA	.000200	43497	8.7	21.3	70.6	8.1
2	224	DANVILLE,VA	.000158	51900	8.2	21.3	70.4	8.3
2	225	BELLINGHAM,WA	.000127	42613	5.4	29.4	60.0	10.6
2	226	BREMERTON,WA	.000220	38206	8.4	29.4	60.0	10.6
2	227	FORT LEWIS,WA	.000172	41178	7.1	30.1	61.5	8.5
2	228	LAKES DISTRICT,WA	.000193	52103	10.1	30.1	61.5	8.5
2	229	LONGVIEW,WA	.000159	30703	4.9	29.4	60.0	10.6
2	230	RICHLAND,WA	.000075	28441	2.1	30.3	61.9	7.8
2	231	YAKIMA,WA	.000250	49332	12.3	29.3	59.8	10.9
2	232	FAIRMONT,WV	.000224	27865	6.2	24.7	66.1	9.2
2	233	MORGANTOWN,WV	.000320	31594	10.1	24.7	66.1	9.2
2	234	PARKERSBURG,WV	.000310	47517	14.7	25.0	67.0	8.0
2	235	BELOIT,WI	.000135	37880	5.1	35.4	58.5	6.1
2	236	EAU CLAIRE,WI	.000115	47288	5.4	35.4	58.5	6.1
2	237	FONDDULAC,WI	.000177	37847	6.7	35.4	58.5	6.1
2	238	JAMESVILLE,WI	.000125	49221	6.1	35.4	58.5	6.1
2	239	MANITOWOC,WI	.000145	35513	5.2	35.4	58.5	6.1
2	240	SHEBOYGAN,WI	.000237	51446	12.2	35.4	58.5	6.1

TABLE 34 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION		
						HEATING	STATIONARY	MOBILE
2	241	WAUSAU, WI	.000133	34781	4.6	35.4	58.5	6.1
2	242	CASPER, WY	.000248	49595	12.3	32.4	54.8	12.9
2	243	CHEYENNE, WY	.000192	51324	9.9	32.4	54.8	12.9

Source: Systems Applications, Incorporated computations.

TABLE 35. BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS IN TYPE III CITIES

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
3	1	ARAB,AL	.000033	4756	.2	10.2	74.4	15.4
3	2	BAY MINETTE,AL	.000041	7273	.3	10.5	76.8	12.6
3	3	IRONDALE,AL	.000040	3423	.1	10.9	79.7	9.4
3	4	CONWAY,AR	.000106	17550	1.9	19.1	70.1	10.8
3	5	ENGLAND,AR	.000088	3479	.3	19.1	70.1	10.8
3	6	LAKE VILLAGE,AR	.000083	3745	.3	19.1	70.1	10.8
3	7	MENA,AR	.000049	5125	.3	19.1	70.1	10.8
3	8	MONTICELLO,AR	.000086	5754	.5	19.1	70.1	10.8
3	9	RUSSELLVILLE,AR	.000098	13295	1.3	19.1	70.1	10.8
3	10	WALNUT RIDGE,AR	.000084	4299	.4	19.1	70.1	10.8
3	11	ALTURAS,CA	.000051	3107	.2	15.6	74.7	9.7
3	12	BANNING,CA	.000046	13360	.6	15.7	75.0	9.4
3	13	CARMEL VALLEY,CA	.000020	3359	.1	15.7	75.2	9.1
3	14	CHINA LAKE,CA	.000075	12329	.9	15.5	73.9	10.7
3	15	CUCAMONGA,CA	.000078	6435	.5	15.3	73.0	11.7
3	16	EUREKA,CA	.000090	27020	2.4	15.6	74.7	9.7
3	17	GRIDLEY,CA	.000139	3923	.5	15.6	74.7	9.7
3	18	LAMONT,CA	.000184	7779	1.4	15.5	73.9	10.7
3	19	NEWHALL,CA	.000111	10715	1.2	15.9	75.8	8.3
3	20	PALMDALE,CA	.000011	9449	.1	15.9	75.8	8.3
3	21	SANTA MARIA,CA	.000129	7915	1.0	15.8	75.4	8.8
3	22	SUISAN CITY,CA	.000090	3238	.3	15.8	75.8	8.4
3	23	BRIGHTON,CO	.000176	10067	1.8	29.7	60.5	9.8
3	24	GOLDEN,CO	.000111	11894	1.3	29.7	60.7	9.6
3	25	DANIELSON,CN	.000182	4711	.9	31.8	61.5	6.7
3	26	ORANGETOWN,CN	.000048	13912	.7	31.8	61.5	6.7
3	27	SIMSBURY CENTER,CN	.000058	5137	.3	31.8	61.5	6.7
3	28	WILLIMANTIC,CN	.000167	14815	2.5	31.8	61.5	6.7
3	29	MEMPHIS,FL	.000088	4103	.4	5.3	84.9	9.8
3	30	MIAMI SHORES,FL	.000172	12059	2.1	5.3	84.9	9.8
3	31	PERRY,FL	.000041	9853	.4	5.3	84.9	9.8
3	32	CARROLLTON,GA	.000067	15069	1.0	18.2	72.1	9.7
3	33	LARKSTON,GA	.000186	3485	.6	18.6	73.9	7.5
3	34	SMYRNATOWN,GA	.000108	21352	2.3	18.0	71.6	10.3
3	35	HALEUVA,HAW	.000040	3114	.1	0.	91.5	8.5
3	36	CHUBBUCK,ID	.000032	3600	.1	28.4	59.9	11.7
3	37	ALSID,IL	.000065	11292	.7	32.3	62.9	4.8
3	38	CENTREVILLE,IL	.000122	11532	1.4	31.3	61.1	7.5
3	39	CHESTER,IL	.000036	5382	.2	31.3	61.1	7.5
3	40	CLARENDON HILLS,IL	.000173	6841	1.2	31.6	61.7	6.7

TABLE 35 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
3	41	EFFINGHAM, IL	.000126	9586	1.2	31.3	61.1	7.5
3	42	HENRY, IL	.000097	2645	.3	31.3	61.1	7.5
3	43	LA GRANGE PARK, IL	.000268	15669	4.2	32.3	62.9	4.8
3	44	LAWRENCEVILLE, IL	.000118	5942	.7	31.3	61.1	7.5
3	45	LYONS, IL	.000228	11275	2.6	32.3	62.9	4.8
3	46	SPARTA, IL	.000112	4365	.5	31.3	61.1	7.5
3	47	AURORA, IN	.000073	4420	.3	29.1	64.0	6.9
3	48	AUSTIN, IN	.000098	5047	.5	29.1	64.0	6.9
3	49	HOBART, IN	.000076	22122	1.7	29.4	64.7	5.9
3	50	DENISON, IA	.000031	6354	.3	31.8	58.1	10.1
3	51	ELDORA, IA	.000032	3293	.1	31.8	58.1	10.1
3	52	MOUNT VERNON, IA	.000094	3084	.3	31.8	58.1	10.1
3	53	ONAWA, IA	.000031	3223	.1	31.8	58.1	10.1
3	54	WINTERSET, IA	.000093	3734	.3	31.8	58.1	10.1
3	55	CONCORDIA, KA	.000085	7503	.6	24.3	63.6	12.1
3	56	MULVANE, KA	.000093	3309	.3	25.0	65.4	9.6
3	57	PHILLPSBURG, KA	.000083	3367	.3	24.3	63.6	12.1
3	58	DAWSON SPRING, KN	.000044	3263	.1	24.7	65.2	10.2
3	59	FORT WRIGHT-LOOKOUT	.000115	5226	.6	24.7	65.2	10.2
3	60	JENKINS, KN	.000023	2767	.1	24.7	65.2	10.2
3	61	OKOLONA, KN	.000140	19133	2.7	25.4	67.1	7.5
3	62	CARIBOU, ME	.000083	11511	1.0	34.9	57.2	7.9
3	63	FARMINGTON CENTER	.000061	3420	.2	34.9	57.2	7.9
3	64	KITTERY CENTER, ME	.000173	8134	1.4	34.9	57.2	7.9
3	65	BAINBRIDGE, MD	.000117	5586	.7	25.7	66.7	7.7
3	66	PALMER PARK, MD	.000386	8684	3.4	25.7	66.8	7.5
3	67	DUXBURYTOWN, MASS	.000014	7778	.1	29.2	63.8	6.9
3	68	GREENFIELDTOWN, MASS	.000036	18453	.7	29.2	63.8	6.9
3	69	HADLEYTOWN, MASS	.000007	3819	.0	29.2	63.8	6.9
3	70	ORANGE CENTER, MASS	.000050	3918	.2	29.2	63.8	6.9
3	71	TEMPLETONTOWN, MASS	.000008	5972	.0	29.2	63.8	6.9
3	72	WARETOWN, MASS	.000011	8339	.1	29.2	63.8	6.9
3	73	WILMINGTONTOWN, MASS	.000041	17420	.7	29.2	63.8	6.9
3	74	FREMONT, MICH	.000063	3575	.2	35.8	57.0	7.3
3	75	GAYLORD, MICH	.000066	3108	.2	35.8	57.0	7.3
3	76	GROSSE ILE, MICH	.000056	8570	.5	36.5	58.1	5.5
3	77	LEVEL PARK-OAK PARK	.000074	3178	.2	35.8	57.1	7.1
3	78	ST. LOUIS, MICH	.000103	4231	.4	35.8	57.0	7.3
3	79	LAKE CITY, MN	.000054	4154	.2	39.0	53.5	7.5
3	80	MINNETRISTA, MN	.000007	3023	.0	39.7	54.4	5.9

TABLE 35 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
3	81	MORA, MN	.000036	2712	.1	38.7	53.1	8.2
3	82	MACON, MISS	.000038	2844	.1	14.1	75.4	10.4
3	83	MORTON, MISS	.000047	2909	.1	14.1	75.4	10.4
3	84	AVA, MISS	.000046	2579	.1	26.3	65.1	8.7
3	85	BUTLER, MISS	.000071	4104	.3	26.3	65.1	8.7
3	86	DEXTER, MISS	.000074	6205	.5	26.3	65.1	8.7
3	87	CENTRAL CITY, NE	.000067	2967	.2	29.1	59.0	11.9
3	88	EXETERTOWN, NH	.000044	10145	.4	34.8	58.1	7.1
3	89	HAMPTONTOWN, NH	.000055	9139	.5	35.2	58.8	6.0
3	90	HILLSBOROGHTOWN, NH	.000007	3166	.0	35.2	58.8	6.0
3	91	HINSDALETOWN, NH	.000016	3737	.1	34.8	58.1	7.1
3	92	NEWMARKET COMPACT, N	.000093	3017	.3	34.8	58.1	7.1
3	93	WOLFEBOROTOWN, NH	.000007	3463	.0	34.8	58.1	7.1
3	94	DUMONT, NJ	.000402	20663	8.3	26.8	66.6	6.6
3	95	KENDALL PARK, NJ	.000100	7599	.8	26.8	66.6	6.6
3	96	LITTLE SILVER, NJ	.000081	6161	.5	26.8	66.6	6.6
3	97	MOORESTOWN-LENOLA	.000085	14527	1.2	26.8	66.6	6.6
3	98	NEW MILFORD, NJ	.000308	19632	6.1	26.8	66.6	6.6
3	99	NORTH CAPE MAY, NJ	.000174	3908	.7	26.8	66.6	6.6
3	100	ELMA CENTER, NY	.000022	2728	.1	32.0	63.2	4.8
3	101	LAKE CARMEL, NY	.000105	4700	.5	32.0	63.2	4.8
3	102	LITTLE FALLS, NY	.000078	7477	.6	31.8	62.8	5.4
3	103	NEWMARK, NY	.000102	11412	1.2	31.3	61.7	7.0
3	104	NEW YORK MILLS, NY	.000147	3729	.5	31.8	62.8	5.3
3	105	NORTH BELLPORT, NY	.000073	5785	.4	31.7	62.6	5.7
3	106	NORTH MASSAPEQUA, NY	.000331	22662	7.5	31.8	62.7	5.6
3	107	RYE, NY	.000123	15553	1.9	31.8	62.9	5.3
3	108	SCOTIA, NY	.000153	7223	1.1	31.7	62.6	5.6
3	109	TICONDEROGA, NY	.000085	3202	.3	32.0	63.2	4.8
3	110	VOORHEESVILLE, NY	.000050	2769	.1	31.9	62.9	5.2
3	111	KERNSVILLE, NC	.000092	5790	.5	19.5	71.1	9.4
3	112	NEW RIVER-GIEGER, NC	.000077	10461	.8	19.4	70.6	10.0
3	113	STANFORD, NC	.000161	14089	2.3	19.4	70.6	10.0
3	114	BRUNSWICK, OH	.000077	15926	1.2	28.9	62.9	8.2
3	115	GREENSVILLE, OH	.000187	6120	1.1	29.0	63.0	8.0
3	116	NEW PHILADELPHIA, OH	.000160	15255	2.4	29.0	63.0	8.0
3	117	ADA, OK	.000086	16525	1.4	20.2	67.3	12.5
3	118	LINDSAY, OK	.000087	4120	.4	20.2	67.3	12.5
3	119	SULPHUR, OK	.000054	5736	.3	20.2	67.3	12.5
3	120	BLAKELY, PA	.000071	6381	.5	28.4	64.6	7.1

TABLE 35 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
3	121	DOYLESTOWN,PA	.000118	8257	1.0	28.5	64.8	6.8
3	122	GETTYSBURG,PA	.000148	7263	1.1	28.4	64.7	6.8
3	123	LIBERTY,PA	.000094	3588	.3	28.3	64.5	7.2
3	124	ST. CLARI,PA	.000139	4369	.6	27.8	63.1	9.1
3	125	SLIPPERY,ROCK,PA	.000118	4941	.6	27.9	63.4	8.8
3	126	TYRONE,PA	.000175	7061	1.2	28.4	64.6	7.0
3	127	VANDERGRIFT,PA	.000234	7876	1.8	28.4	64.6	7.0
3	128	WEST WARWICKTOWN,RI	.000130	23886	3.1	30.1	61.8	8.2
3	129	CAPEHART,SC	.000134	5054	.7	15.8	74.9	9.3
3	130	CONWAY,SC	.000096	9176	.9	15.8	74.9	9.3
3	131	MOBRIDGE,SD	.000125	4722	.6	34.6	54.2	11.2
3	132	LA FOLLETTE,TN	.000161	7651	1.2	19.7	69.9	10.4
3	133	ROCKWOOD,TN	.000075	5829	.4	19.7	69.9	10.4
3	134	BURNET,TX	.000036	3341	.1	13.2	74.8	12.0
3	135	CROWLEY,TX	.000020	3105	.1	13.4	75.9	10.7
3	136	FRONIA,TX	.000095	3629	.3	13.2	74.9	12.0
3	137	LOCKHART,TX	.000070	7569	.5	13.2	74.8	12.0
3	138	LULING,TX	.000084	5505	.5	13.2	74.8	12.0
3	139	PORTLAND,TX	.000085	8518	.7	13.5	76.8	9.6
3	140	SAN AUGUSTINE,TX	.000025	2961	.1	13.2	74.8	12.0
3	141	SEALY,TX	.000062	3132	.2	13.2	74.8	12.0
3	142	SILSKEE,TX	.000068	8482	.6	13.3	75.2	11.6
3	143	PRICE,UT	.000188	7621	1.4	29.8	61.1	9.2
3	144	RADFORD,VI	.000113	12973	1.5	21.3	70.6	8.1
3	145	LYDEN,WA	.000096	3038	.3	29.4	60.0	10.6
3	146	STEILACOOM,WA	.000080	3084	.2	30.1	61.5	8.5
3	147	HARTLAND,WI	.000043	2929	.1	35.5	58.6	5.9
3	148	MEDFORD,WI	.000061	3661	.2	35.4	58.5	6.1
3	149	SOUTH MILWAUKEE,WI	.000208	24699	5.1	36.1	59.6	4.3
3	150	GREEN RIVER,WY	.000046	5270	.2	32.4	54.8	12.9

Source: Systems Applications, Incorporated computations.

TABLE 36. SUMMARY OF BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.002500	505140	1758.9	13.8	82.4	3.8	100.0	0.	0.
.001000	9149730	16754.3	30.8	66.6	2.6	100.0	0.	0.
.000500	28601329	30552.2	28.9	66.7	4.4	100.0	0.	0.
.000250	73351092	45256.6	27.7	67.2	5.1	97.8	.8	1.3
.000100	139664758	56842.5	26.9	67.4	5.8	94.2	2.5	3.3
0.	158679135	58136.8	26.8	67.4	5.8	92.8	2.6	4.6

TABLE 28. EXPOSURE/DOSAGE ANALYSIS DATA BASE FOR TYPE I CITY AREA SOURCES

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	1	ABILENE,TX	INNER CITY	74.9	89486	46430	15722
			URBAN FRINGE	3.1	1085	563	191
1	2	AKRON,OH	INNER CITY	54.2	275420	152800	18612
			URBAN FRINGE	149.8	267365	148323	18066
1	3	ALBANY,GA	INNER CITY	29.4	72623	34362	7490
			URBAN FRINGE	3.6	3889	1840	401
1	4	ALBANY,NY	INNER CITY	41.3	256657	110021	15177
			URBAN FRINGE	109.7	229868	98538	13593
1	5	ALBUQUERQUE,NM	INNER CITY	82.8	243751	125567	36807
			URBAN FRINGE	31.8	53700	27663	8109
1	6	ALLENTOWN,PA	INNER CITY	41.8	212461	100710	15304
			URBAN FRINGE	57.2	151110	71629	10942
1	7	ALTOONA,PA	INNER CITY	9.1	62898	30066	4592
			URBAN FRINGE	10.9	18897	9031	1300
1	8	AMARILLO,TX	INNER CITY	61.0	122010	74794	20640
1	9	ANDERSON,IN	INNER CITY	37.1	70853	33153	7318
			URBAN FRINGE	5.9	9851	4609	1017
1	10	ANN ARBOR,MI	INNER CITY	21.8	99797	47793	7201
			URBAN FRINGE	23.2	78808	37741	8617
1	11	APPLETON,WI	INNER CITY	12.7	57406	25054	4183
			URBAN FRINGE	24.3	72486	31836	5315
1	12	ASHEVILLE,NC	INNER CITY	22.3	57571	28933	7705
			URBAN FRINGE	15.7	14800	7478	1992
1	13	ATLANTA,GA	INNER CITY	131.5	497024	292325	53721
			URBAN FRINGE	303.5	675754	397445	73038
1	14	ATLANTIC CITY,NJ	INNER CITY	12.4	47809	24998	2782
			URBAN FRINGE	54.6	86127	44958	5004
1	15	AUGUSTA,GA	INNER CITY	15.2	59864	30977	5826
			URBAN FRINGE	42.7	89089	46100	8671
1	16	AURORA,IL	INNER CITY	28.7	129908	63824	13389
			URBAN FRINGE	48.3	102929	50538	10602
1	17	AUSTIN,TX	INNER CITY	72.1	251817	127158	20884
			URBAN FRINGE	13.9	12682	6404	1455
1	18	BAKERSFIELD,CA	INNER CITY	25.9	69515	34446	12817
			URBAN FRINGE	31.1	107640	53337	19846
1	19	BALTIMORE,MD	INNER CITY	78.3	905759	401240	57892
			URBAN FRINGE	231.7	674022	298580	43080
1	20	BATON ROUGE,LA	INNER CITY	40.4	165970	73027	28215
			URBAN FRINGE	44.6	83493	36737	14194
1	21	BAY CITY,MI	INNER CITY	10.0	49449	23307	4566
			URBAN FRINGE	16.0	28648	13503	2646

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	43	CHATTANOGA,TENN	INNER CITY	52.5	119876	62453	13517
			URBAN FRINGE	64.5	103683	54008	11689
1	44	CHICAGO,IL	INNER CITY	301.0	3692790	1595941	143498
			URBAN FRINGE	976.0	3021708	1303949	117424
1	45	CINCINNATI,OH	INNER CITY	78.1	452550	231191	26254
			URBAN FRINGE	256.9	657964	336130	38171
1	46	CLEVELAND,OH	INNER CITY	75.9	751046	395283	30272
			URBAN FRINGE	570.1	1208834	636225	48724
1	47	COLORADO SPRINGS,CO	INNER CITY	60.8	135017	75402	18172
			URBAN FRINGE	29.2	69749	38952	9388
1	48	COLUMBIA,MO	INNER CITY	42.0	58577	23228	6628
1	49	COLUMBIA,SC	INNER CITY	103.0	241781	128389	25141
1	50	COLUMBUS,GA	INNER CITY	69.5	154098	76198	12532
			URBAN FRINGE	36.5	54518	26958	4434
1	51	COLUMBUS,OH	INNER CITY	135.0	539377	28955	31764
			URBAN FRINGE	100.0	250642	134552	14760
1	52	CORPUS CHRISTI,TX	INNER CITY	101.0	204599	97249	26486
			URBAN FRINGE	29.0	8230	3912	1065
1	53	DALLAS,TX	INNER CITY	266.0	844189	491794	113305
			URBAN FRINGE	408.0	494495	276960	66370
1	54	DANBURY,CONN	INNER CITY	44.0	50781	31281	2723
			URBAN FRINGE	11.0	15870	9776	851
1	55	DAVENPORT,IOWA	INNER CITY	84.0	195041	103278	19448
			URBAN FRINGE	34.0	70078	37108	6988
1	56	DAYTON,OH	INNER CITY	38.3	243459	137573	16201
			URBAN FRINGE	185.7	442483	250037	29445
1	57	DECATUR,IL	INNER CITY	30.6	90705	47720	11197
			URBAN FRINGE	6.4	8988	4729	1110
1	58	DENVER,CO	INNER CITY	95.2	514678	307477	70739
			URBAN FRINGE	201.8	532633	318203	73207
1	59	DES MOINES,IOWA	INNER CITY	63.2	200772	107236	22047
			URBAN FRINGE	45.8	55052	29404	6045
1	60	DETROIT,MI	INNER CITY	138.0	1511336	745256	86724
			URBAN FRINGE	734.0	2459248	1212682	141118
1	61	DUBUQUE,IOWA	INNER CITY	16.4	62313	27073	5966
			URBAN FRINGE	2.6	3237	1409	310
1	62	DULUTH MN	INNER CITY	105.0	132790	58774	15802
			URBAN FRINGE	6.0	5562	2462	662
1	63	DURHAM,NC	INNER CITY	36.6	95412	54903	13266
			URBAN FRINGE	6.4	5352	3080	744

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	22	BEAUMONT,TX	INNER CITY	71.6	115965	57382	16164
			URBAN FRINGE	3.4	385	190	40
1	23	BILLINGS,MONT	INNER CITY	14.7	61581	32949	12414
			URBAN FRINGE	12.3	9616	5145	1939
1	24	BILOXI,MS	INNER CITY	37.0	89236	38853	9814
			URBAN FRINGE	27.0	32635	14092	3560
1	25	BINGHAMTON,NY	INNER CITY	11.0	64123	27873	4156
			URBAN FRINGE	41.0	103101	44816	6683
1	26	BIRMINGHAM,AL	INNER CITY	79.5	300687	162547	34785
			URBAN FRINGE	145.5	257412	139151	29779
1	27	BLOOMINGTON,IL	INNER CITY	15.6	66032	31258	7172
			URBAN FRINGE	4.4	3090	1455	334
1	28	BOISE CITY,ID	INNER CITY	23.4	74990	42983	8336
			URBAN FRINGE	5.6	10187	5839	1132
1	29	BOSTON,MASS	INNER CITY	46.0	541053	316039	36989
			URBAN FRINGE	618.0	2011522	991680	116065
1	30	BOULDER,CO	INNER CITY	13.0	66870	39949	9191
			URBAN FRINGE	1.0	1764	1054	242
1	31	BRIDGEPORT,CONN	INNER CITY	16.1	156546	96432	8391
			URBAN FRINGE	132.9	256820	158201	13766
1	32	BRISTOL,CONN	INNER CITY	26.6	55487	34180	2974
			URBAN FRINGE	10.4	16248	10007	871
1	33	BROCKTON,MASS	INNER CITY	21.2	89040	43897	5138
			URBAN FRINGE	31.8	59804	29483	3451
1	34	BROWNSVILLE,TX	INNER CITY	15.0	55627	21086	5835
1	35	BRYAN,TX	INNER CITY	16.8	33719	14892	4328
			URBAN FRINGE	16.2	17676	7886	2269
1	36	BUFFALO,NY	INNER CITY	41.3	462783	190212	19944
			URBAN FRINGE	172.7	623811	256397	26884
1	37	CANTON,OH	INNER CITY	19.0	109939	59330	8172
			URBAN FRINGE	58.0	134340	72098	9985
1	38	CEDAR RAPIDS,IOWA	INNER CITY	50.7	110642	56838	11445
			URBAN FRINGE	11.3	21366	10976	2210
1	39	CHAMPAIGN-URBANA,IL	INNER CITY	13.4	89377	40114	7637
			URBAN FRINGE	4.6	11040	4955	946
1	40	CHARLESTON,SC	INNER CITY	17.2	66934	30334	5360
			URBAN FRINGE	81.8	161465	73174	13412
1	41	CHARLESTON,WV	INNER CITY	27.2	71505	30359	8001
			URBAN FRINGE	34.8	86157	36579	9640
1	42	CHARLOTTE,NC	INNER CITY	76.0	241215	137723	20478
			URBAN FRINGE	30.0	38315	21876	4524

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	64	EL PASO,TX	INNER CITY	119.0	337471	182847	32407
1	65	ERIE,PA	INNER CITY	18.9	129220	61077	9503
			URBAN FRINGE	25.1	46043	21746	3886
1	66	EUGENE,OR	INNER CITY	26.1	76341	45744	7430
			URBAN FRINGE	28.9	62914	37698	6123
1	67	EVANSVILLE,IN	INNER CITY	36.0	138690	65281	18915
			URBAN FRINGE	5.0	3786	1782	516
1	68	FALL RIVER,MASS	INNER CITY	33.0	96931	53603	7638
			URBAN FRINGE	10.0	42461	23481	3346
1	69	FARGO,ND	INNER CITY	18.0	83029	40270	13129
			URBAN FRINGE	8.0	2417	1172	382
1	70	FAYETTEVILLE,NC	INNER CITY	23.4	53510	23714	4069
			URBAN FRINGE	49.6	107860	47800	8203
1	71	FITCHBURG,MASS	INNER CITY	56.3	76202	37607	4401
			URBAN FRINGE	4.7	1771	873	102
1	72	FLINT,MI	INNER CITY	32.8	193380	93678	17633
			URBAN FRINGE	63.2	136748	66244	12469
1	73	FORT LAUDERDALE,FL	INNER CITY	55.0	246555	171970	21076
			URBAN FRINGE	157.0	367242	256148	31392
1	74	FORT SMITH,AR	INNER CITY	45.0	62802	28558	13782
			URBAN FRINGE	15.0	12715	5782	2790
1	75	FORT WAYNE,IN	INNER CITY	51.5	177738	83953	18295
			URBAN FRINGE	17.5	47446	22411	4884
1	76	FORT WORTH,TX	INNER CITY	205.0	393463	219896	52810
			URBAN FRINGE	191.0	283481	158438	38048
1	77	FRESNO,CA	INNER CITY	41.8	165972	82731	28396
			URBAN FRINGE	37.2	96936	48319	16584
1	78	GADSDEN,AL	INNER CITY	32.4	53911	31933	7424
			URBAN FRINGE	22.6	13795	8171	1900
1	79	GAINSVILLE,FL	INNER CITY	26.1	64510	36566	7478
			URBAN FRINGE	2.9	4819	2732	559
1	80	GALVESTON,TX	INNER CITY	23.0	61809	28575	7178
1	81	GRAND RAPIDS,MI	INNER CITY	44.9	197534	101048	17873
			URBAN FRINGE	101.1	155169	79377	14040
1	82	GREAT FALLS,MT	INNER CITY	14.7	60091	29336	10705
			URBAN FRINGE	7.3	10814	5328	1926
1	83	GREEN BAY,WI	INNER CITY	41.7	87684	38983	6635
			URBAN FRINGE	36.3	41421	18378	3134
1	84	GREENSBORO,NC	INNER CITY	54.4	144245	83323	16416
			URBAN FRINGE	6.6	8007	4625	911

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	85	GREENSVILLE,SC	INNER CITY	20.7	61208	32624	6607
			URBAN FRINGE	50.3	96865	51630	10456
1	86	HAMILTON,OH	INNER CITY	16.0	67617	35751	5009
			URBAN FRINGE	22.0	23295	12317	1726
1	87	HARLINGEN,TX	INNER CITY	22.5	33515	12728	3512
			URBAN FRINGE	11.5	16954	6439	1781
1	88	HARRISBURY,PA	INNER CITY	7.6	67880	32002	4888
			URBAN FRINGE	70.4	172871	81499	12449
1	89	HARTFORD,CONN	INNER CITY	17.4	158017	97338	8470
			URBAN FRINGE	113.6	306987	189104	16455
1	90	HIGH POINT,NC	INNER CITY	30.8	63105	36453	7182
			URBAN FRINGE	21.2	30442	17585	3464
1	91	HONOLULU,HAWAII	INNER CITY	83.9	324871	160760	17600
			URBAN FRINGE	31.1	117524	58159	6396
1	92	HOUSTON,TX	INNER CITY	434.0	1232407	646833	161293
			URBAN FRINGE	105.0	445456	233799	58300
1	93	HUNTINGTON,WV	INNER CITY	22.7	103567	47136	11320
			URBAN FRINGE	33.3	64016	29136	6997
1	94	HUNSVILLE,AL	INNER CITY	109.1	137878	83438	21552
			URBAN FRINGE	13.9	8687	5257	1358
1	95	INDIANAPOLIS,IN	INNER CITY	381.0	820259	364704	72469
1	96	JACKSON,MI	INNER CITY	10.7	45481	21970	4553
			URBAN FRINGE	25.3	33891	18985	3313
1	97	JACKSON,MS	INNER CITY	50.2	153968	75600	19696
			URBAN FRINGE	21.8	46092	22632	8896
1	98	JACKSONVILLE,FL	INNER CITY	351.0	529585	295540	57369
1	99	JOHNSTOWN,PA	INNER CITY	5.7	42476	29168	3038
			URBAN FRINGE	22.3	53670	25483	3892
1	100	JOLIET,IL	INNER CITY	16.5	78644	38614	8100
			URBAN FRINGE	38.5	76856	37736	7916
1	101	KALAMAZOO,MI	INNER CITY	24.5	85661	41104	8605
			URBAN FRINGE	48.5	66422	31872	6672
1	102	KANSASCITY,MO	INNER CITY	373.0	675391	337822	65388
			URBAN FRINGE	120.0	426396	213278	41282
1	103	KENOSHA,WI	INNER CITY	13.7	78817	37654	5358
			URBAN FRINGE	4.3	5445	2601	370
1	104	KNOXVILLE,TENN	INNER CITY	77.0	174587	89902	16401
			URBAN FRINGE	9.0	15915	8195	1498
1	105	LA CROSSE,WI	INNER CITY	15.2	51153	22366	4357
			URBAN FRINGE	8.8	12220	5343	1041

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	106	LAFAYETTE, LA	INNER CITY	20.0	68984	30383	11727
			URBAN FRINGE	5.0	9560	4206	1625
1	107	LAFAYETTE, IN	INNER CITY	8.7	44955	18329	4155
			URBAN FRINGE	10.3	34162	13928	3157
1	108	LAKE CHARLES, LA	INNER CITY	23.0	77998	34319	13264
			URBAN FRINGE	11.0	10262	4515	1745
1	109	LANCASTER, PA	INNER CITY	7.2	57509	27051	4132
			URBAN FRINGE	31.8	59508	27953	4270
1	110	LANSING, MI	INNER CITY	33.4	131638	61761	12479
			URBAN FRINGE	39.6	97808	45923	9279
1	111	LAREDO, TX	INNER CITY	20.5	68937	24973	3175
			URBAN FRINGE	1.5	1260	456	58
1	112	LAS VEGAS, NV	INNER CITY	51.6	125641	77418	18779
			URBAN FRINGE	69.4	111040	68421	16596
1	113	LAWRENCE, MASS	INNER CITY	39.1	113047	55732	6523
			URBAN FRINGE	44.9	87233	43006	5033
1	114	LAWTON, OK	INNER CITY	31.2	74627	42118	12551
			URBAN FRINGE	12.8	21060	11886	3542
1	115	LEWISTON, MAINE	INNER CITY	34.6	41779	21266	6016
			URBAN FRINGE	33.4	23433	11927	3374
1	116	LEXINGTON, KY	INNER CITY	23.0	108137	56230	13659
			URBAN FRINGE	17.0	51401	26728	6492
1	117	LIMA, OH	INNER CITY	11.7	53482	29939	5309
			URBAN FRINGE	15.3	16813	9412	1669
1	118	LINCOLN, NEB	INNER CITY	49.3	149518	71662	14482
			URBAN FRINGE	2.7	3925	1881	308
1	119	LITTLE ROCK, AR	INNER CITY	49.3	149518	72982	21207
			URBAN FRINGE	45.7	73098	35608	10368
1	120	LORAIN, OH	INNER CITY	40.0	132148	74633	8463
			URBAN FRINGE	66.0	60117	33952	3050
1	121	LOS ANGELES, CA	INNER CITY	590.0	3619982	1946951	313020
			URBAN FRINGE	982.0	4731284	2544647	409117
1	122	LOUISVILLE, KY	INNER CITY	60.0	361453	183982	32064
			URBAN FRINGE	150.0	377943	192376	33527
1	123	LOWELL, MASS	INNER CITY	13.6	94251	46466	5438
			URBAN FRINGE	48.4	98488	48551	5682
1	124	LUBBOCK, TX	INNER CITY	77.0	150135	75574	21438
1	125	LYNCHBURG, VA	INNER CITY	25.1	54083	24822	6244
			URBAN FRINGE	11.9	16759	7691	1935
1	126	MACON, GA	INNER CITY	49.0	122423	64267	12802
			URBAN FRINGE	2.0	5642	2962	598

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1975 TRUCK
1	127	MADISON,WI	INNER CITY	48.8	173242	79782	12384
			URBAN FRINGE	20.5	32215	14836	2303
1	128	MANCHESTER,NH	INNER CITY	32.1	87754	47387	1863
			URBAN FRINGE	6.9	7386	3988	746
1	129	MANSFIELD,OH	INNER CITY	24.1	55001	33563	4968
			URBAN FRINGE	16.9	22598	13790	2041
1	130	MCALLEN,TX	INNER CITY	13.5	37636	13435	4715
			URBAN FRINGE	19.5	53505	19100	6703
1	131	MEMPHIS,MS	INNER CITY	196.0	663976	295718	69658
1	132	MERIDEN,CONN	INNER CITY	23.7	55959	34471	2999
			URBAN FRINGE	47.3	42495	26177	2278
1	133	MIAMI,FL	INNER CITY	34.3	335075	210362	21150
			URBAN FRINGE	224.7	884595	553353	35055
1	134	MIDLAND,TX	INNER CITY	29.2	59689	37054	9118
			URBAN FRINGE	2.8	682	423	104
1	135	MILWAUKEE,WI	INNER CITY	95.0	717124	323759	32492
			URBAN FRINGE	362.0	535333	241686	24255
1	136	MINNEAPOLIS,MN	INNER CITY	107.0	744321	369808	60958
			URBAN FRINGE	614.0	960102	477010	70630
1	137	MOBILE,AL	INNER CITY	116.6	189986	94947	22252
			URBAN FRINGE	51.4	67830	33898	7944
1	138	MODESTO,CA	INNER CITY	9.5	61712	32010	12132
			URBAN FRINGE	24.5	44396	23028	8727
1	139	MONROE,LA	INNER CITY	22.2	56374	24805	9584
			URBAN FRINGE	17.8	34193	15045	5813
1	140	MONTGOMERY,AL	INNER CITY	4.6	413347	107069	1516
			URBAN FRINGE	4.6	5512	2919	626
1	141	MUNCIE,IN	INNER CITY	12.8	69132	29635	7454
			URBAN FRINGE	12.2	21295	9129	2296
1	142	MUSKEGON,MI	INNER CITY	13.0	44631	20517	4105
			URBAN FRINGE	39.0	61085	28081	5618
1	143	NASHUA,NH	INNER CITY	31.4	55280	30143	5638
			URBAN FRINGE	2.6	5141	2776	519
1	144	NASHVILLE,TENN	INNER CITY	344.0	448444	220683	49134
1	145	NEW BEDFORD,MASS	INNER CITY	19.5	101759	50167	5071
			URBAN FRINGE	14.5	31908	15731	1841
1	146	NEW BRITAIN,CONN	INNER CITY	13.3	83441	51400	4472
			URBAN FRINGE	25.7	47908	29511	2568
1	147	NEW HAVEN,CONN	INNER CITY	18.4	137715	84832	7382
			URBAN FRINGE	88.6	210626	129746	11298

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
I	148	NEW ORLEANS, LA	INNER CITY	184.0	961728	423160	163494
I	149	NEW YORK, NY	INNER CITY	362.0	8820151	2017343	113814
			URBAN FRINGE	2063.0	7386690	1689480	95317
I	150	NEWPORT, VA	INNER CITY	123.8	258956	120482	17525
			URBAN FRINGE	19.2	9307	4327	630
I	151	NORFORK, VA	INNER CITY	81.6	418914	182706	32194
			URBAN FRINGE	217.4	249345	108750	19163
I	152	NORWALK, CONN	INNER CITY	22.0	79192	48782	4245
			URBAN FRINGE	20.0	27515	16949	1475
I	153	ODESSA, TX	INNER CITY	18.4	78380	44214	14840
			URBAN FRINGE	6.6	3265	1842	619
I	154	OGDEN, UT	INNER CITY	21.0	69485	36053	10410
			URBAN FRINGE	40.0	80242	41635	12022
I	155	OKLAHOMA CITY, OK	INNER CITY	339.0	579780	327223	97514
I	156	OMAHA, IOWA	INNER CITY	76.6	347380	166945	30668
			URBAN FRINGE	74.4	143396	68914	12660
I	157	ORLANDO, FL	INNER CITY	27.5	98965	66361	12316
			URBAN FRINGE	104.5	206514	138496	25700
I	158	OSHKOSH, KY	INNER CITY	13.0	55400	27962	10097
I	159	OWENSBORO, KY	INNER CITY	8.5	50317	26353	7522
			URBAN FRINGE	3.5	2816	1475	421
I	160	OXNARD, CA	INNER CITY	70.0	162773	84111	17343
			URBAN FRINGE	42.0	81880	42310	8724
I	161	PENSACOLA, FL	INNER CITY	24.0	59571	30929	6396
			URBAN FRINGE	42.0	107048	55578	11493
I	162	PEORIA, IL	INNER CITY	37.4	126964	64330	12482
			URBAN FRINGE	69.6	120158	60881	11813
I	163	PETERSBURG, VA	INNER CITY	8.0	36103	18011	3255
			URBAN FRINGE	34.0	64514	26824	5817
I	164	PHILADELPHIA, PA	INNER CITY	128.5	1948609	941871	143927
			URBAN FRINGE	623.5	2072457	1001734	153073
I	165	PHOENIX, ARIZ	INNER CITY	248.0	581600	327709	97127
			URBAN FRINGE	140.0	281757	158759	47053
I	166	PINE BLUFF, AR	INNER CITY	16.1	57295	22549	7790
			URBAN FRINGE	4.9	3612	1422	491
I	167	PITTSBURG, PA	INNER CITY	55.0	520167	282889	38630
			URBAN FRINGE	541.0	1325875	644599	98465
I	168	PITTSFIELD, MASS	INNER CITY	.4	57124	28162	3296
			URBAN FRINGE	3.6	5748	2834	332
I	169	PORT ARTHUR, TX	INNER CITY	48.2	57380	28378	7998
			URBAN FRINGE	24.8	590[illegible]4	29226	8237

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	170	PORTLAND,MAINE	INNER CITY	21.6	65116	33144	9377
			URBAN FRINGE	34.4	41483	21115	5974
1	171	PORTLAND,OR	INNER CITY	89.0	381077	210013	40945
			URBAN FRINGE	170.0	443049	252936	56786
1	172	PROVIDENCE,RI	INNER CITY	61.8	339824	187923	26770
			URBAN FRINGE	182.2	435487	251884	35892
1	173	PROVO,UT	INNER CITY	36.2	70882	32426	13269
			URBAN FRINGE	28.8	25228	10371	4244
1	174	PUEBLO,CO	INNER CITY	22.5	97453	49325	16908
			URBAN FRINGE	9.5	5847	2959	1014
1	175	RACINE,WI	INNER CITY	13.1	95193	44549	5862
			URBAN FRINGE	14.9	22215	10396	1368
1	176	RALEIGH,NC	INNER CITY	44.9	121128	69701	16841
			URBAN FRINGE	26.1	31161	17931	4333
1	177	READING,PA	INNER CITY	10.0	87621	41726	6374
			URBAN FRINGE	31.0	80311	38244	5842
1	178	RENO,NEV	INNER CITY	30.3	72063	46260	14678
			URBAN FRINGE	7.7	26824	17030	5403
1	179	RICHMOND,VA	INNER CITY	60.3	249621	123947	24024
			URBAN FRINGE	85.3	166942	82893	16067
1	180	ROANOKE,VA	INNER CITY	26.6	92115	49512	11062
			URBAN FRINGE	39.4	64506	34672	7747
1	181	ROCHESTER,MN	INNER CITY	13.4	53766	26252	5703
			URBAN FRINGE	1.6	2838	1386	301
1	182	ROCHESTER,NY	INNER CITY	36.7	296233	131147	18376
			URBAN FRINGE	109.3	305128	138085	10928
1	183	ROCKFORD,IL	INNER CITY	34.2	147205	75891	11891
			URBAN FRINGE	26.8	58879	30355	4756
1	184	SACRAMENTO,CA	INNER CITY	93.8	254364	131411	34433
			URBAN FRINGE	150.2	379368	195991	51355
1	185	SAGINAW,MI	INNER CITY	17.3	91828	43597	7927
			URBAN FRINGE	26.7	55732	26451	4812
1	186	ST. JOSEPH,MO	INNER CITY	28.7	72987	31733	9574
			URBAN FRINGE	3.3	4236	1842	556
1	187	ST. LOUIS,MO	INNER CITY	61.2	622236	290578	42740
			URBAN FRINGE	399.8	1260708	588738	86598
1	188	ST. PETERSBURG,FL	INNER CITY	55.4	216067	137089	20634
			URBAN FRINGE	105.6	279092	177077	26653
1	189	SALEM,OR	INNER CITY	24.6	68249	39423	7097
			URBAN FRINGE	12.4	24792	14321	2578

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	190	SALINAS,CA	INNER CITY	13.3	58896	28674	6729
			URBAN FRINGE	1.7	3560	1733	407
1	191	SALT LAKE CITY,UT	INNER CITY	59.3	175813	91247	26337
			URBAN FRINGE	124.7	303529	157531	45469
1	192	SAN ANGELO,TX	INNER CITY	34.0	63884	33821	11664
1	193	SAN ANTONIO,TX	INNER CITY	184.0	654289	307364	68677
			URBAN FRINGE	39.0	118224	55538	12409
1	194	SAN BERNARDINO,CA	INNER CITY	116.0	244163	123078	44334
			URBAN FRINGE	194.0	339434	171102	61632
1	195	SAN DIEGO,CA	INNER CITY	317.0	696566	365132	70058
			URBAN FRINGE	64.0	501757	263015	50465
1	196	SAN FRANCISCO,CA	INNER CITY	114.0	1143713	582407	105806
			URBAN FRINGE	567.0	1044137	939078	170604
1	197	SAN JOSE,CA	INNER CITY	136.0	446504	246514	44669
			URBAN FRINGE	141.0	578769	319538	57901
1	198	SANTA BARBARA,CA	INNER CITY	21.0	70211	36959	7604
			URBAN FRINGE	16.0	59563	31354	6450
1	199	SANTA ROSA,CA	INNER CITY	20.0	49873	27871	8746
			URBAN FRINGE	18.0	25210	14088	4421
1	200	SAVANNAH,GA	INNER CITY	27.0	118344	59147	11069
			URBAN FRINGE	37.0	45409	22695	4247
1	201	SCRANTON,PA	INNER CITY	25.7	103494	60647	10298
			URBAN FRINGE	72.3	100711	59017	10021
1	202	SEASIDE,CA	INNER CITY	16.9	62251	30307	7112
			URBAN FRINGE	7.1	31033	15109	3548
1	203	SEATTLE,WA	INNER CITY	113.0	584622	305528	70916
			URBAN FRINGE	300.0	653485	341516	79269
1	204	SHERMAN,TX	INNER CITY	19.1	29079	16705	5895
			URBAN FRINGE	15.9	26264	15036	5324
1	205	SHREVEPORT,LA	INNER CITY	57.0	182200	80203	30980
			URBAN FRINGE	37.0	52284	23005	8888
1	206	SIMI VALLEY,CA	INNER CITY	23.0	56676	29287	6039
			URBAN FRINGE	2.0	260	134	28
1	207	SIOUX CITY,IOWA	INNER CITY	52.0	85925	42327	11338
			URBAN FRINGE	8.0	10012	4932	1321
1	208	SIOUX FALLS,SD	INNER CITY	2.5	7248	39028	9974
			URBAN FRINGE	2.0	2658	1431	366
1	209	SOUTH BEND,IN	INNER CITY	29.2	125802	57040	11139
			URBAN FRINGE	73.8	162770	73802	14411
1	210	SPOKANE,WA	INNER CITY	50.8	170516	89295	26367
			URBAN FRINGE	27.2	59104	30951	9139

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	211	SPRINGFIELD, IL	INNER CITY	28.2	91607	47820	10069
			URBAN FRINGE	8.8	29187	15236	3208
1	212	SPRINGFIELD, MO	INNER CITY	61.5	119999	56800	19084
			URBAN FRINGE	1.5	1341	635	213
1	213	SPRINGFIELD, OH	INNER CITY	16.7	81850	48258	6692
			URBAN FRINGE	8.3	11803	6526	965
1	214	SPRINGFIELD, MASS	INNER CITY	86.3	200594	138333	16190
			URBAN FRINGE	151.7	233714	115221	13485
1	215	STAMFORD, CONN	INNER CITY	38.1	108853	67053	5835
			URBAN FRINGE	31.9	76045	46843	4076
1	216	STEUBENVILLE, OH	INNER CITY	27.2	58028	27217	4722
			URBAN FRINGE	11.8	27464	12882	2235
1	217	STOCKTON, CA	INNER CITY	29.9	107459	52478	18199
			URBAN FRINGE	17.1	52914	25841	8961
1	218	SYRACUSE, NY	INNER CITY	25.8	197270	83652	13563
			URBAN FRINGE	70.2	178899	75862	12300
1	219	TACOMA, WA	INNER CITY	47.7	154585	75814	20397
			URBAN FRINGE	81.3	177966	86952	23466
1	220	TALLAHASSEE, FL	INNER CITY	26.1	71934	37572	7164
			URBAN FRINGE	3.9	5919	3092	589
1	221	TAMPA, FL	INNER CITY	84.5	277736	176217	26523
			URBAN FRINGE	46.5	91006	57741	8691
1	222	TERRE HAUTE, IN	INNER CITY	26.1	70316	29331	9766
			URBAN FRINGE	5.9	10592	4418	1471
1	223	TEXARKANA, TX	INNER CITY	16.2	30497	14694	5710
			URBAN FRINGE	14.8	20073	13434	5256
1	224	TEXAS CITY, TX	INNER CITY	83.0	84054	40531	9290
1	225	TOLEDO, OH	INNER CITY	81.2	384015	207234	30515
			URBAN FRINGE	84.8	103774	56002	8246
1	226	TOPEKA, KANS	INNER CITY	47.5	124938	68940	19686
			URBAN FRINGE	5.5	7170	3956	1130
1	227	TRENTON, NJ	INNER CITY	7.5	104578	54590	6076
			URBAN FRINGE	57.5	169570	88816	9852
1	228	TUCSON, ARIZ	INNER CITY	80.0	262933	150768	42120
			URBAN FRINGE	25.0	31251	17920	5006
1	229	TULSA, OK	INNER CITY	172.0	331800	186269	58893
			URBAN FRINGE	8.0	39699	22287	7047
1	230	TUSCALOOSA, AL	INNER CITY	27.4	65773	30424	7365
			URBAN FRINGE	16.6	20102	9298	2251
1	231	TYLER, TX	INNER CITY	23.1	57770	30038	9819
			URBAN FRINGE	1.9	2011	1045	342

TABLE 28 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	232	UTICA,NY	INNER CITY	16.0	91654	36340	6194
			URBAN FRINGE	59.0	88701	35169	5994
1	233	VINELAND,NJ	INNER CITY	69.5	47643	24870	2768
			URBAN FRINGE	15.5	25936	13539	1507
1	234	WACO,TX	INNER CITY	58.7	95326	49294	14516
			URBAN FRINGE	31.3	23517	12161	3581
1	235	WASHINGTON,DC	INNER CITY	61.4	756516	264024	21258
			URBAN FRINGE	433.6	1724973	602016	48472
1	236	WATERBURY,CONN	INNER CITY	27.6	108033	66548	5791
			URBAN FRINGE	32.4	48953	30155	2624
1	237	WATERLOO,IOWA	INNER CITY	59.2	75578	38693	8361
			URBAN FRINGE	9.8	37303	19097	4127
1	238	WEST PALM BEACH,FL	INNER CITY	38.4	57328	38623	5394
			URBAN FRINGE	97.6	230233	155111	21663
1	239	WHEELING,WV	INNER CITY	13.3	48280	20884	4022
			URBAN FRINGE	14.7	44664	19320	3720
1	240	WICHITA,KANS	INNER CITY	86.5	276699	163334	42821
			URBAN FRINGE	18.5	25635	15132	3967
1	241	WICHITA FALLS,TX	INNER CITY	42.0	97564	55811	14980
1	242	WILKES,PA	INNER CITY	6.7	58817	34467	5852
			URBAN FRINGE	76.3	164013	96117	16319
1	243	WILMINGTON,DEL	INNER CITY	12.9	80386	41077	8842
			URBAN FRINGE	97.1	290881	148640	31997
1	244	WILMINGTON,NC	INNER CITY	17.5	46169	25309	5422
			URBAN FRINGE	11.5	11476	6311	1348
1	245	WINSTON,NC	INNER CITY	56.5	132901	76770	15124
			URBAN FRINGE	9.5	9683	5593	1102
1	246	WORCESTER,MASS	INNER CITY	37.4	176603	87065	10190
			URBAN FRINGE	46.6	70813	34911	4086
1	247	YORK,PA	INNER CITY	5.3	50355	23724	3624
			URBAN FRINGE	31.7	72771	34298	5239
1	248	YOUNGSTOWN,OH	INNER CITY	45.6	203174	112421	13196
			URBAN FRINGE	83.4	192366	106441	12494

Source: U.S. Census Bureau (1973) and U.S. Federal Highway Administration (1978).

TABLE 29. EXPOSURE/DOSAGE ANALYSIS DATA BASE FOR TYPE II CITY AREA SOURCES

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	1	ANNISTON,AL	16.1	31508	16899	3693
2	2	BESSEMER,AL	14.4	33484	17937	3266
2	3	DECATUR,AL	26.6	38044	20277	6467
2	4	DOTHAN,AL	49.0	36733	19579	6245
2	5	FLORENCE,AL	32.4	53911	29909	8270
2	6	PHENIX CITY,AL	19.9	25281	13475	4298
2	7	SELMA,AL	13.2	27379	14593	4654
2	8	ANCHORAGE,AL	16.2	48157	22206	8525
2	9	FLAGSTAFF,AR	64.1	26117	12327	4701
2	10	YUMA,AR	7.9	29007	13691	5221
2	11	EL DORADO,AR	16.0	25283	10821	8360
2	12	FAYETTEVILLE,AR	18.1	30639	13358	6252
2	13	HOTSPRING,AR	23.4	35631	15250	7554
2	14	JONESBORO,AR	12.0	27026	11567	8730
2	15	WEST MEMPHIS,AR	8.7	25929	11098	5497
2	16	ANTIOCH,CA	7.4	20005	18023	2771
2	17	CONCORD,CA	25.8	85067	45635	8416
2	18	CORONA,CA	23.2	27506	14211	3588
2	19	FAIRFIELD,CA	15.4	44146	21550	4667
2	20	LANCASTER,CA	14.5	32570	17517	2816
2	21	LIVERMORE,CA	11.9	37703	18898	3589
2	22	LODI,CA	7.1	20691	14011	4859
2	23	LOMPOC,CA	9.9	25320	13328	2742
2	24	NAPA,CA	13.1	35978	19138	5280
2	25	NEWARK,CA	8.4	27151	13609	2584
2	26	NOVATO,CA	20.5	30833	17731	2496
2	27	OCEANSIDE,CA	35.2	40491	21225	4072
2	28	REDLANDS,CA	21.8	36414	18034	7920
2	29	REDWOOD CITY,CA	20.5	55539	33006	5561
2	30	SAN LUIS OBISPO,CA	9.1	28036	14971	3701
2	31	SAN RAFAEL,CA	14.3	38949	22398	3153
2	32	SANTA CRUZ,CA	12.2	32076	18781	4874
2	33	SANTA MARIA,CA	14.3	32749	17239	3547
2	34	VISALIA,CA	12.4	27268	14561	3599
2	35	WALNUT CREEK,CA	14.7	39833	21369	3941
2	36	FORT COLLINS,CO	10.8	43368	25370	8630
2	37	GREELEY,CO	7.7	38902	22758	7741
2	38	MIDDLETOWN,CON	44.0	36903	22732	1978
2	39	MILFORD,CON	22.3	50858	31329	2726
2	40	NEW LONDON,CON	6.1	31606	19469	1694

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	41	NORWICH,CON	26.1	41433	25823	2221
2	42	SHELTON,CON	30.5	27194	16752	1458
2	43	TORRINGTON,CON	39.6	31952	19682	1713
2	44	DAYTONA BEACH,FL	22.8	45327	17628	4629
2	45	FORT MYERS,FL	12.0	27351	18190	3526
2	46	FORT PIERCE,FL	10.6	29728	17064	2567
2	47	KEY WEST,FL	4.1	27323	15683	3279
2	48	LAKELAND,FL	12.6	41550	24952	6462
2	49	MELBOURNE,FL	23.9	40312	25846	3537
2	50	MERRITT ISLAND,FL	16.2	29233	18743	2565
2	51	PANAMA CITY,FL	13.8	32125	18440	3855
2	52	POMPANO BEACH,FL	11.5	37711	26300	3224
2	53	SARASOTA,FL	14.0	40237	31313	4538
2	54	TITUSVILLE,FL	15.2	30515	19568	2678
2	55	ATHENS,GA	14.7	44342	23191	6518
2	56	ROME,GA	13.5	30756	16085	4521
2	57	VALDOSTA,GA	11.1	32502	16996	4778
2	58	WARNER ROBINS,GA	15.5	33430	19004	3309
2	59	HILO,HA	56.1	26359	12626	2167
2	60	IDAHO FALLS,ID	9.4	35776	18317	11019
2	61	LEWISTON,ID	15.1	26068	13347	8209
2	62	POCATELLO,ID	13.7	40036	20498	12331
2	63	ALTON,IL	11.0	39700	19493	4009
2	64	BELLEVILLE,IL	9.6	41908	20577	4316
2	65	DANVILLE,IL	12.9	42690	20961	4397
2	66	DE KALB,IL	3.4	32928	16168	3392
2	67	EAST ST. LOUIS,IL	13.9	69947	34344	7205
2	68	FREEPORT,IL	8.3	27736	13618	2857
2	69	GALESBURG,IL	12.2	36290	17818	3738
2	70	KANKAKEE,IL	7.6	30886	15165	3181
2	71	PEKIN,IL	9.1	31297	15806	2674
2	72	QUINCY,IL	11.9	45288	22236	4665
2	73	BLOOMINGTON,IN	8.4	42776	21388	6416
2	74	COLUMBUS,IN	8.7	27295	13648	4094
2	75	ELKHART,IN	15.6	43594	21797	6539
2	76	KOKOMO,IN	9.2	44042	22021	6606
2	77	MARION,IN	9.6	39836	19918	5975
2	78	MICHIGAN,IN	20.6	39273	19639	5891
2	79	NEW ALBANY,IN	11.3	38402	19201	5760
2	80	RICHMOND,IN	13.7	44010	22005	6602

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	81	AMES, IA	16.8	39699	22033	8218
2	82	BURLINGTON, IA	13.0	32444	18006	6716
2	83	CLINTON, IA	33.1	34719	19269	7187
2	84	FORT DODGE, IA	14.5	31263	17351	6471
2	85	IOWA CITY, IA	21.1	46850	26002	9698
2	86	MARSHALLTOWN, IA	14.6	26366	14633	5458
2	87	MASON CITY, IA	15.2	30491	16923	6312
2	88	OTTUMWA, IA	11.9	29695	16481	6147
2	89	HUTCHINSON, KA	13.4	36885	20508	9406
2	90	LAWRENCE, KA	16.7	45580	25342	11623
2	91	LEAVENWORTH, KA	8.9	25147	13982	6412
2	92	MANHATTAN, KA	7.4	27555	15321	7027
2	93	OVERLAND PARK, KA	46.2	76868	42739	19601
2	94	PRAIRIE VILLAGE, KA	6.3	28104	15626	7167
2	95	SALINA, KA	15.8	37714	20969	9617
2	96	BOWLING GREEN, KE	16.2	36253	18272	6598
2	97	FORT KNOX, KE	20.2	37502	18901	6825
2	98	PADUCAH, KE	11.9	31627	15940	5756
2	99	ALEXANDRIA, LA	12.0	41507	18263	7056
2	100	BOSSIER CITY, LA	21.1	41750	18370	7098
2	101	HOUMA, LA	8.5	30893	13593	5252
2	102	KENNER, LA	14.2	29910	13160	5085
2	103	NEW IBERIA, LA	7.5	30147	13265	5125
2	104	BANGOR, ME	34.3	33165	16883	4776
2	105	ANNAPOLIS, MD	5.8	29592	15006	2409
2	106	CUMBERLAND, MD	8.0	29820	15307	2639
2	107	HAGERSTOWN, MD	8.5	35862	18505	3174
2	108	ATTLEBORO, MASS	27.0	32907	16223	1899
2	109	GLOUCESTER, MASS	24.7	27937	13773	1612
2	110	MARLBOROUGH, MASS	20.5	27936	13772	1612
2	111	TAUNTON, MASS	47.0	43756	21572	2525
2	112	BATTLECREEK, MICH	11.8	38931	19708	3988
2	113	HOLLAND, MICH	13.8	26337	13669	2818
2	114	MIDLAND, MICH	24.9	35206	18272	3767
2	115	PORT HURON, MICH	7.5	35829	16509	3537
2	116	YPSILANTI, MICH	4.1	29502	14129	2129
2	117	AUSTIN, MN	7.3	25031	13091	4388
2	118	MANKATO, MN	9.8	30895	16158	5407
2	119	ST. CLOUD, MN	10.8	39691	16453	5501
2	120	WINONA, MN	13.0	26383	13798	4617

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	121	COLUMBUS, MI	8.3	25795	11350	4488
2	122	GREENVILLE, MI	8.0	39648	17445	6899
2	123	HATTIESBURG, MI	17.5	38274	16841	6660
2	124	MERIDIAN, MI	25.4	45083	19837	7844
2	125	PASCAGOULA, MI	14.9	27471	12087	4780
2	126	VICKSBURG, MI	10.5	25586	11258	4452
2	127	CAPE GIRARDEAU, MO	18.5	30918	14439	4576
2	128	FERGUSON, MO	5.8	28837	14944	1514
2	129	FLORISSANT, MO	9.0	66006	34207	3465
2	130	FORT LEONARDWOOD, MO	12.2	33848	15807	5010
2	131	JEFFERSON CITY, MO	18.8	32250	15061	4773
2	132	JOPLIN, MO	28.7	39227	18319	5806
2	133	KIRKWOOD, MO	8.9	31800	16521	1674
2	134	RAYTOWN, MO	10.0	33635	15569	2762
2	135	ST. CHARLES, MO	9.5	31834	15741	3863
2	136	MISSOULA, MT	7.9	29403	15290	9527
2	137	GRAND ISLAND, NE	11.1	31269	16635	7817
2	138	CONCORD, NH	63.3	30022	16212	3032
2	139	PORTSMOUTH, NH	15.2	26188	14142	2645
2	140	LONG BRANCH, NJ	5.1	31774	16586	1846
2	141	NEW BRUNSWICK, NJ	5.6	41855	21848	2432
2	142	OLD BRIDGE, NJ	6.0	25176	13142	1463
2	143	PERTH AMBOY, NJ	4.7	38777	20242	2253
2	144	SAYREVILLE, NJ	16.2	32508	16969	1889
2	145	CLOVIS, NM	11.4	28553	14505	7110
2	146	HOBBS, NM	16.6	26109	13263	6501
2	147	LAS CRUCES, NM	17.8	37857	19231	9426
2	148	ROSWELL, NM	24.2	33908	17225	8443
2	149	SANTA FE, NM	29.4	41167	20913	10251
2	150	AMSTERDAM, NY	5.8	25524	10800	1705
2	151	AUBURN, NY	8.5	34599	12871	1754
2	152	ELMIRA, NY	7.3	39945	17068	2751
2	153	ITHACA, NY	5.6	26226	9756	1330
2	154	JAMESTOWN, NY	9.5	39795	14804	2018
2	155	KINGSTON, NY	7.7	25544	9502	1295
2	156	NEWBURGH, NY	3.9	26219	9753	1329
2	157	NIAGARA FALLS, NY	13.4	85615	37243	4528
2	158	NORTH TONARVANDA, NY	10.0	36012	15666	1905
2	159	POUGHKEEPSIE, NY	4.8	33029	15009	1792
2	160	WATERTOWN, NY	9.2	30787	11453	1561

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	161	BURLINGTON,NC	15.2	36198	21194	4314
2	162	CAMP LEJEUNE,NC	16.4	34517	18950	8592
2	163	CHAPEL HILL,NC	7.8	25541	14213	4138
2	164	GASTONIA,NC	19.9	47153	24006	5079
2	165	GOLDSBORO,NC	9.0	26821	14725	4345
2	166	GREENVILLE,NC	11.4	29078	15964	4710
2	167	KANNAPOLIS,NC	29.9	36236	19894	8870
2	168	ROCKY MOUNT,NC	12.4	34315	18839	5589
2	169	WILSON,NC	8.1	29347	16116	4754
2	170	BISMARCK,ND	10.9	34670	18098	12273
2	171	GRAND FORKS,ND	9.2	39044	20381	13822
2	172	MINOT,ND	8.1	32270	16845	11424
2	173	ALLIANCE,OH	6.2	26547	13975	1835
2	174	AUSTINTOWN,OH	8.2	29363	15457	1698
2	175	BOARDMAN,OH	9.5	30060	16245	1784
2	176	FAIRBORN,OH	7.5	32279	18659	2918
2	177	FINDLAY,OH	11.4	35800	15278	3210
2	178	LANCASTER,OH	13.1	32911	19517	3724
2	179	MARION,OH	7.1	30681	22358	3497
2	180	MASSILON,OH	8.9	32600	18843	2947
2	181	NEWARK,OH	13.3	41822	29173	3781
2	182	PORTSMOUTH,OH	12.2	27633	15972	2498
2	183	SANDUSKY,OH	9.1	32674	18862	2954
2	184	XENIA,OH	6.0	25373	14666	2294
2	185	ZANESVILLE,OH	8.1	33045	19110	2987
2	186	BARLESVILLE,OK	9.3	29672	25606	11644
2	187	ENID,OK	23.5	44540	24145	11493
2	188	MUSKOGEE,OK	22.5	37331	20233	9631
2	189	PONCA,OK	18.7	25940	14059	3627
2	190	SHAWNEE,OK	32.5	25131	13570	5929
2	191	STILLWATER,OK	17.3	31126	16870	8031
2	192	CORVALLIS,OR	7.9	35153	20740	5414
2	193	MEDFORD,OR	12.2	28454	16788	4382
2	194	LEBANON,PA	4.6	28572	16743	2843
2	195	NEW CASTLE,PA	7.7	38559	22596	3837
2	196	STATE COLLEGE,PA	4.3	33778	19794	3361
2	197	WILLIAMSPORT,PA	9.1	37918	18132	2770
2	198	NEWPORT,RI	7.3	34562	19113	2723
2	199	WOONSOCKET,RI	7.9	46820	25891	3689
2	200	ANDERSON,SC	10.8	27556	13585	3555

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	201	FLORENCE,SC	9.8	25997	12817	3354
2	202	ROCK HILL,SC	14.1	33846	16686	4366
2	203	SPARTANBURG,SC	16.3	44546	21472	4421
2	204	ABERDEEN,SD	5.6	26476	13264	7652
2	205	RAPID CITY,SD	16.5	43836	21962	12669
2	206	CLARKSVILLE,TN	25.8	31719	12803	3216
2	207	JACKSON,TN	17.3	39996	20438	6159
2	208	JOHNSON CITY,TN	15.6	33770	14829	4144
2	209	KINGSPORT,TN	17.4	31920	12563	3802
2	210	MURFREESBORO,TN	11.5	26360	13067	3316
2	211	OAK RIDGE,TN	82.7	28384	18804	3271
2	212	BIG SPRING,TX	12.8	28824	15190	5505
2	213	DENTON,TX	27.6	39874	19274	6835
2	214	FORT HOOD,TX	8.2	32677	13629	3868
2	215	KILLEEN,TX	26.0	35507	14809	4204
2	216	KINGSVILLE,TX	10.8	28605	15075	5464
2	217	LONGVIEW,TX	22.6	45500	24021	8706
2	218	MESQUITE,TX	25.8	55209	31552	6336
2	219	RICHARDSON,TX	28.0	48662	24243	8245
2	220	TEMPLE,TX	22.6	33431	13943	3958
2	221	VICTORIA,TX	16.6	41349	21791	7098
2	222	BURLINGTON,VT	10.1	38633	19819	4945
2	223	CHARLOTTESVILLE,VA	10.4	38880	21345	4160
2	224	DANVILLE,VA	16.7	46391	23799	5938
2	225	BELLINGHAM,WA	20.8	39379	21500	7718
2	226	BREMERTON,WA	9.8	35307	19348	6920
2	227	FORT LEWIS,WA	13.8	38053	18592	5017
2	228	LAKES DISTRICT,WA	15.8	48149	23525	6349
2	229	LONGVIEW,WA	11.1	28373	15548	5561
2	230	RICHLAND,WA	23.1	26283	11413	3330
2	231	YAKIMA,WA	11.4	45588	24369	9608
2	232	FAIRMONT,WV	8.7	25919	10800	4017
2	233	MORGANTOWN,WV	6.7	29307	12254	4555
2	234	PARKERSBURG,WV	10.9	44198	18921	4858
2	235	BELOIT,WI	12.8	35729	17043	3400
2	236	EAU CLAIRE,WI	19.9	44603	21276	4344
2	237	FONDDULAC,WI	9.4	35698	17028	3477
2	238	JANESVILLE,WI	19.0	46426	22145	4522
2	239	MANITOWOC,WI	11.0	33497	15978	3263
2	240	SHEBOYGAN,WI	9.6	48525	23146	4726

TABLE 29 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	241	WAUSAU, WI	11.9	32806	15648	8198
2	242	CASPER, WY	8.2	39406	21678	14847
2	243	CHEYENNE, WY	11.4	40063	22434	15364

Sources: U.S. Census Bureau (1973) and U.S. Federal Highway Administration (1978).

TABLE 30. EXPOSURE/DOSAGE ANALYSIS DATA BASE FOR TYPE III CITY AREA SOURCES

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
3	1	ARAB, AL	6.1	4399	3467	921
3	2	BAY MINETTE, AL	7.4	6727	3665	1295
3	3	IRONDALE, AL	3.1	3166	1616	309
3	4	CONWAY, AR	8.8	15510	6638	3288
3	5	ENGLAND, AR	1.7	3075	1316	652
3	6	LAKE VILLAGE, AR	2.0	3310	1417	702
3	7	MENA, AR	5.2	4530	1939	960
3	8	MONTICELLO, AR	3.1	5085	2176	1078
3	9	RUSSELLVILLE, AR	7.0	11750	5029	2491
3	10	WALNUT RIDGE, AR	2.3	3800	1626	806
3	11	ALTURAS, CA	2.4	2799	1520	369
3	12	BANNING, CA	14.3	12034	6217	1570
3	13	CARMEL VALLEY, CA	7.4	3026	1561	366
3	14	CHINA LAKE, CA	7.6	11105	5503	2047
3	15	CUCAMONGA, CA	3.5	5796	2960	1261
3	16	EUREKA, CA	14.9	24337	13215	3212
3	17	GRIDLEY, CA	1.0	3534	1919	466
3	18	LAMONT, CA	1.6	7007	3472	1292
3	19	NEWHALL, CA	4.0	9651	5191	835
3	20	PALMDALE, CA	47.4	8511	4578	736
3	21	SANTA MARIA, CA	2.4	7129	3753	772
3	22	SUISAN CITY, CA	1.3	2917	1424	308
3	23	BRIGHTON, CO	2.7	8309	4806	1807
3	24	GOLDEN, CO	5.5	9817	6348	1559
3	25	DANIELSON, CN	1.1	4580	2821	245
3	26	ORANGETOWN, CN	17.4	13524	8331	725
3	27	SIMSBURY CENTER, CN	4.5	4994	3076	268
3	28	WILLIMANTIC, CN	4.5	14402	8872	772
3	29	MEMPHIS, FL	1.5	3207	1841	385
3	30	MIAMI SHORES, FL	2.4	9425	5410	1131
3	31	PERRY, FL	9.8	7701	4420	924
3	32	CARROLLTON, GA	10.5	13520	7071	1987
3	33	LARKSTON, GA	.6	3127	1627	219
3	34	SMYRNATOWN, GA	9.2	19157	12470	2460
3	35	HALEUVA, HAW	1.8	2626	1257	216
3	36	CHUBBUCK, ID	6.0	2924	1520	900
3	37	ALSID, IL	8.0	11141	4512	346
3	38	CENTREVILLE, IL	4.1	11378	5587	1172
3	39	CHESTER, IL	7.0	5310	2607	547
3	40	CLARENDON HILLS, IL	1.5	6750	3688	358

TABLE 30 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
3	41	EFFINGHAM, IL	3.2	9458	4644	974
3	42	HENRY, IL	1.0	2610	1201	269
3	43	LA GRANGE PARK, IL	2.3	15459	6260	480
3	44	LAWRENCEVILLE, IL	2.0	5063	2879	604
3	45	LYONS, IL	1.9	11124	4508	345
3	46	SPARTA, IL	1.5	4307	2115	444
3	47	AURORA, IN	2.5	4293	2147	322
3	48	AUSTIN, IN	2.1	4902	2451	368
3	49	HOBART, IN	15.0	21485	9106	1330
3	50	DENISON, IA	5.5	6218	3451	1287
3	51	ELDORA, IA	4.4	3223	1709	667
3	52	MOUNT VERNON, IA	1.2	3018	1675	625
3	53	ONAWA, IA	4.5	3154	1750	653
3	54	WINTERSET, IA	1.5	3654	2028	756
3	55	CONCORDIA, KA	2.9	7221	4015	1041
3	56	MULVANE, KA	1.0	3185	1881	454
3	57	PHILLPSBURG, KA	1.2	3241	1802	826
3	58	DAWSON SPRING, KN	3.7	3009	1517	548
3	59	FORT WRIGHT, KN	2.1	4819	2429	877
3	60	JENKINS, KN	6.5	2552	1286	464
3	61	OKOLONA, KN	7.1	17643	9166	1386
3	62	CARIBOU, ME	8.2	10419	5303	1500
3	63	FARMINGTON, ME	2.9	3096	1876	445
3	64	KITTERY CENTER, ME	2.4	7363	3748	1060
3	65	BAINBRIDGE, MD	1.9	8257	2713	465
3	66	PALMER PARK, MD	.8	8172	4217	676
3	67	DUXBURYTOWN, MASS	23.3	7636	3765	441
3	68	GREENFIELDTOWN, MASS	21.8	18116	8931	1045
3	69	HADLEYTOWN, MASS	23.2	3750	1849	216
3	70	ORANGE CENTER, MASS	2.5	3847	1897	222
3	71	TEMPLETONTOWN, MASS	31.9	5863	2890	338
3	72	WARETOWN, MASS	34.2	8187	4036	472
3	73	WILMINGTONTOWN, MASS	17.2	17102	8431	987
3	74	FREMONT, MICH	2.6	3465	1798	371
3	75	GAYLORD, MICH	2.1	3012	1563	322
3	76	GROSSE ILE, MICH	7.9	8306	3945	404
3	77	LEVEL PARK, MICH	1.9	3000	1559	316
3	78	ST. LOUIS, MICH	1.8	4101	2128	439
3	79	LAKE CITY, MN	3.3	3954	1808	629
3	80	MINNETRISTA, MN	26.1	2878	1514	203

TABLE 30 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
3	81	MORA,MN	3.5	2882	1380	462
3	82	MACON,MISS	3.5	2612	1149	454
3	83	MORTON,MISS	2.8	2672	1176	465
3	84	AVA,MISS	2.2	2504	1169	371
3	85	BUTLER,MISS	2.3	3984	1861	590
3	86	DEXTER,MISS	3.5	6024	2813	892
3	87	CENTRAL CITY,NE	1.7	2803	1941	701
3	88	EXETERTOWN,NH	20.0	8892	4802	898
3	89	HAMPTONTOWN,NH	13.3	8011	4326	437
3	90	HILLSBOROGHTOWN,NH	44.5	2775	1499	181
3	91	HINSDALETOWN,NH	20.5	3276	1769	331
3	92	NEWMARKET COMPACT,N	2.1	2645	1428	267
3	93	WOLFEBOROTOWN,NH	47.4	3036	1639	307
3	94	DUMONT,NJ	1.8	20155	10521	1171
3	95	KENDALL PARK,NJ	2.8	7412	3069	431
3	96	LITTLE SILVER,NJ	2.8	6010	3137	349
3	97	MOORESTOWN,NJ	7.1	14170	7397	823
3	98	NEW MILFORD,NJ	2.3	1/149	9996	1113
3	99	NORTH CAPE MAY,NJ	.7	3812	1990	221
3	100	ELMA CENTER,NY	5.4	2784	1130	114
3	101	LAKE CARMEL,NY	1.7	4796	1784	243
3	102	LITTLE FALLS,NY	4.1	7629	3012	530
3	103	NEWMARK,NY	5.0	11644	5241	1318
3	104	NEW YORK MILLS,NY	.9	3805	1511	248
3	105	NORTH BELLPORT,NY	3.3	5903	2922	283
3	106	NORTH MASSAPEQUA,NY	2.8	23123	12350	642
3	107	RYE,NY	5.6	15869	7933	454
3	108	SCOTIA,NY	1.8	7370	3469	379
3	109	TICONDEROGA,NY	1.4	3268	1216	166
3	110	VOORHEESVILLE,NY	2.2	2826	1159	159
3	111	KERNSVILLE,NC	3.0	4815	2923	575
3	112	NEW RIVER-GIEGER,NC	7.3	8699	4776	1409
3	113	STANFORD,NC	4.4	11716	6432	1898
3	114	BRUNSWICK,OH	10.7	15852	9276	1476
3	115	GREENSVILLE,OH	1.3	6092	3521	551
3	116	NEW PHILADELPHIA,OH	4.4	15184	8776	1373
3	117	ADA,OK	6.5	14859	8054	3834
3	118	LINDSAY,OK	1.3	3705	2008	956
3	119	SULPHUR,OK	3.3	5158	2796	1331
3	120	BLAKELY,PA	4.0	6391	3071	469

TABLE 30 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
3	121	DOYLESTOWN, PA	3.0	8270	3791	879
3	122	GETTYSBURG, PA	2.0	7275	3379	316
3	123	LIBERTY, PA	1.5	3594	1761	269
3	124	ST. CLAIR, PA	1.3	4576	2862	455
3	125	SLIPPERY ROCK, PA	1.7	4949	2900	492
3	126	TYRONE, PA	1.6	7072	3300	516
3	127	VANDERGRIFT, PA	1.3	7809	3777	577
3	128	WEST WARWICKTOWN, RI	8.3	24323	13481	1917
3	129	CAPEHART, SC	1.8	4490	2214	879
3	130	CONWAY, SC	5.2	8151	4018	1081
3	131	MOBRIDGE, SD	1.5	4545	2277	1314
3	132	LA FOLLETTE, TN	2.0	6902	3527	1063
3	133	ROCKWOOD, TN	3.5	5239	2687	810
3	134	BURNET, TX	3.6	2064	1509	547
3	135	CROWLEY, TX	6.3	2662	1509	358
3	136	FRONIA, TX	1.3	3111	1639	594
3	137	LOCKHART, TX	4.3	6489	3420	1239
3	138	LULING, TX	2.4	4719	2487	901
3	139	PORTLAND, TX	3.8	7302	3872	912
3	140	SAN AUGUSTINE, TX	4.7	2539	1338	485
3	141	SEALY, TX	1.8	2688	1415	513
3	142	SILSBEE, TX	8.0	7271	3163	1516
3	143	PRICE, UT	1.9	6218	3068	1380
3	144	RADFORD, VI	8.0	11596	6366	1241
3	145	LYDEN, WA	1.4	2800	1539	550
3	146	STEILACOOM, WA	1.7	2050	1392	376
3	147	HARTLAND, WI	2.4	2763	1434	206
3	148	MEDFORD, WI	2.2	3454	1648	336
3	149	SOUTH MILWAUKEE, WI	4.7	23297	10025	814
3	150	GREEN RIVER, WY	4.3	4196	2304	1578

Source: U.S. Census Bureau (1973) and U.S. Federal Highway Administration (1978).

SECTION 4

UNCERTAINTIES

The data and data-based estimations described in Sections 2 and 3 are subject to uncertainties that may be evaluated subjectively or objectively. Quantification of uncertainty has been undertaken where feasible. If data for the quantification of some aspects of uncertainty were not available within the scope of this program, an effort was made to subjectively describe the parameters of the uncertainty factor and evaluate its qualitative effect.

Review of uncertainty is presented in two parts:

> Uncertainty of Emissions Estimation
> Uncertainty of Exposure/Dosage Estimation.

UNCERTAINTIES INVOLVED IN EMISSION ESTIMATIONS

A number of factors could cause the estimated emissions of a specific chemical to be considerably higher or lower than the actual amount calculated. This is true to a greater degree for individual plant sites and to a lesser degree for total industry sources. The primary factors that could cause emission estimate deviations are listed and discussed below:

> A primary source of error would occur if production or use quantities were estimated too high or too low. The effect on emissions and, in turn, on ambient concentrations would be directly proportional.

> Not all plants operate at the same level of capacity. By distributing total production of a chemical based on the ratio of individual site capacity compared to total industry capacity, error is automatically built in. Plants that operate below the average industry level of capacity would have emissions estimated too low. This type of averaging necessarily leads to underestimates of the exposure and dosage at the highest concentration levels; in fact, the averaging will lead to underestimates of the maximum concentrations. Depending on population patterns, however, the effect on total dosage may be relatively little.

> The omission of significant sources of emissions in any summary for a specific chemical would render the total emissions estimate too low.

> The use and efficiency of control devices is not uniform for all producers or users of a specific chemical. Emission factors derived from a plant without control devices would make emissions estimates from those plants that do use control devices too high. Conversely, if the emissions factor were derived from a plant with an effective control device, the emissions estimates from those plants not employing a similar device would be too low.

> In general, old plants have greater associated emissions than do new plants producing or using the same chemical. Emission factors derived primarily from old plant data would cause emissions estimates to be too high, and emissions factors derived primarily from modern, new plants would cause emissions estimates to be too low.

> Emissions estimates derived by assuming that all the chemical is lost to the atmosphere when it is used in solvent applications are probably too high. Some portion of most solvents normally is disposed of by encapsulation for burial or is burned for the heat value of the solvent.

There is a level of uncertainty or confidence associated with each source identified and each emissions estimate. Although that level cannot be quantified, it can be assumed to vary as a function of the quality of the available information on sources and emissions. Uncertainty levels were defined according to this rationale, as shown in Table 37. It should be noted that emissions uncertainty levels 1, 2, 3, and 4 correspond with levels A, B, C, and D, respectively, used in the individual chemical emissions summaries. These defined uncertainty levels are necessarily subjective. They were assigned by HI on the basis of the nature of data used to identify the sources and generate the emissions estimates. Even with the highest level of confidence (level 1), attempts to quantify the uncertainty would represent a formidable task. A complete listing of the levels of uncertainty assigned to the emissions of the 35 chemicals from the production, use, and incidental sources is shown as Table 38. A composite uncertainty, based on emissions-weighted averages of the component uncertainties, is also presented for each chemical.

UNCERTAINTIES IN EXPOSURE/DOSAGE ESTIMATIONS

Estimating human exposure to toxic chemicals requires detailed knowledge of both population distribution and concentration patterns over the surface of the earth within a given time period. The ideal estimate would require error-free characterizations of concentrations, $c(\bar{x},t)$,at all spatial coordinates $\bar{x}$ and times t and, similarly, of population densities, $p(\bar{x},t)$, for all $\bar{x}$ and t. At each instant t, the total dosage would be given by

$$D(t) = \int c(\bar{x},t)\, p(\bar{x},t)\, d\bar{x} \qquad (31)$$

and the exposure at level L by

TABLE 37. DEFINITION OF UNCERTAINTY LEVELS IN CHEMICAL SOURCE LOCATIONS AND EMISSIONS ESTIMATIONS

Uncertainty Type	Uncertainty Level	Definition	Example
Sources	1	Complete data of reasonable accuracy on site locations and individual site capacities.	Complete data on ethylene oxide-producing locations are available along with total industry and individual plant capacities to allow for the distribution of total industry production.
	2	Partially estimated data of indeterminate accuracy on site locations or individual site capacities.	Complete data on peracetic acid-producing locations are available but total use of acetaldehyde to produce peracetic acid must be distributed evenly over all sites because total and individual site capacity data are not available.
	3	Complete data of indeterminate accuracy on regional site locations using an average production or use quantity per site.	Complete data on regional locations of phenolic resin plants are available and an average use of phenol per site can be determined.
	4	Site locations and production or use quantities of indeterminate accuracy estimated without data.	The total number of quaternary ammonium comcompound-producing locations was estimated, and total benzyl chloride usage to produce it was evenly distributed over the estimated sites.
	5	Unable to identify site locations.	Site locations for miscellaneous uses of phenol could not be identified.
Emissions	1	Emissions estimated from company site visit data of reasonable accuracy.	Emissions data were obtained from site visits by HI personnel to various companies (i.e., chlorobenzene production emission factor).
	2	Emissions estimated from data of indeterminate accuracy supplied by a company to state agencies.	Emissions data were obtained from various state agencies emissions inventory questionnaires (i.e., phosgene emissions factor from its use to produce TDI).
	3	Emissions estimated from data of indeterminate accuracy obtained from other published sources.	Emissions data were obtained from other previously published emissions information (i.e. pentaerythritol formaldehyde use emissions factor).
	4	Emissions of indeterminate accuracy estimated without data.	Emissions data and emissions estimates made by HI personnel (i.e., mixed xylene emissions factor from ethyl benzene production).

Source: Hydroscience, Incorporated, Knoxville, Tennessee.

TABLE 38. LEVELS OF UNCERTAINTY FOR ASSESSED CHEMICALS

Chemical	Source Location	Emissions Estimates
Acetaldehyde	1.2*	2.6*
Production	1	2
Use		
Acetic acid	1	2/3
Peracetic acid	2	2
Pentaerythritol	1	3
Pyridenes	1	3
Glyoxal	2	4
1,3-butylene glycol	2	2
Miscellaneous	5	4
Acrolein	1.3*	1.8*
Production	1	1
Use		
Acrylic acid and esters	1	1
Glycerin	1	1
Methionine	2	4
Miscellaneous	5	4
Allyl Chloride	1.0*	2.0*
Production	1	2
Use		
Epichlorohydrin	1	2
Benzyl Chloride	1.6*	2.8*
Production	1	2/3
Use		
Butyl benzyl phthalate	2	3
Quarternary ammonium compounds	2	4
Benzyl alcohol	1	3
Miscellaneous	5	4

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* Composite level of uncertainty based on weighted average of total emissions.

Source: Hydroscience, Incorporated, Knoxville, Tennessee estimates.

TABLE 38 (Continued)

Chemical	Source Location	Emissions Estimates
Beryllium	4.9*	3.0*
Production	5	3
Use		
Beryllium alloy	2	3
Beryllium fabrication	5	3
Beryllium oxide	5	3
Incidental		
Gray iron foundries	4	3
Coal burning	3/5	3
Oil burning	3/5	3
Carbon Tetrachloride	4.7*	4.0*
Production	1	1
Use		
Solvents	4	4
Nitrochlorobenzene	1	3
DDT	1	3
Diphenyl oxide	2	2
Miscellaneous	5	4
Chloroform	4.8*	3.9*
Production	1	1
Use		
Fluorocarbons	1	1
Solvents, miscellaneous	5	4
Chlorprene	2.0*	2.0*
Production	2	2
Use		
Neoprene	2	2

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* Composite level of uncertainty based on weighted average of total emissions.

TABLE 38 (Continued)

Chemical	Source Location	Emissions Estimates
Cresols (m-, o-, p- isomers)	4.7*	3.9*
Production	1/2	2/4
Use		
BHT/antioxidants	1/2	4
Phenolic resins	4	4
Pesticides	3	3
Pyrethroid pesticides	4	4
TCP production	1	3
Solvent	3	3
Disinfectant/cleaning	5	4
Ore flotation	4	4
Miscellaneous	5	4
Incidental		
Coke ovens	3	3
Dichlorobenzenes (o- and p- isomers)	4.8*	3.9*
Production	1	1
Use		
3,4-Dichloroaniline	2	3
Toluene diisocyanate solvent	1	4
Miscellaneous solvents	5	4
Dye manufacturing	5	4
Pesticide intermediates	5	4
Space deodorant	5	4
Moth control	5	4
Dimethylamine	2.2*	3.3*
Production	2	3
Use		
Dimethyl formide	2	4
Lauryl dimethylamine oxide	2	4
Rubber chemical accelerators	4	4
Dimethyl hydrazine/pesticides	4	4

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* Composite level of uncertainty based on weighted average of total emissions.

TABLE 38 (Continued)

Chemical	Source Location	Emissions Estimates
2,3,7,8-TCDD (Dioxin)	4.3*	3.3*
Incidental		
Trichlorophenol	2	4
2,4,5-T	2	3
Pentachlorophenol	1	4
Burning	5	3
Application of 2,4,5-T	5	1
Application of pentachlorophenol	5	4
Epichlorohydrin	2.2*	2.3*
Production	1	2
Use		
Glycerin	1	2
Epoxy resins	2	2
Miscellaneous	5	4
Elastomers	5	4
Ethylene Oxide	1.0*	1.0*
Production	1	1
Use		
All	1	1
Formaldehyde	1.7*	3.7*
Production	1	1
Use		
Resins	1	4
Butanediol	1	4
Pentaerythritol	1	3
Hexamethylene tetramine	1	3
Trimethylopropane	1	2
Miscellaneous	5	4

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 38 (Continued)

Chemical	Source Location	Emissions Estimates
Hexachlorocyclopentadiene	4.0*	4.0*
Production	4	4
Use		
Pesticides	4	3
Flame retardants	4	4
Resins	4	4
Manganese	4.0*	3.0*
Production	5	3
Use		
All	3	3
Incidental		
All	3/5	3
Methylene Chloride	4.5*	3.7*
Production	1	1
Use		
Solvents	3	3/4
Miscellaneous	5	4
Morpholine	4.7*	4.0*
Production	2	1
Use		
Rubber chemicals	3	4
Corrosion inhibitor	5	4
Optical brightener	4	4
Polishes and waxes	4	4
Miscellaneous	5	4

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 38 (Continued)

Chemical	Source Location	Emissions Estimates
Nickel	3.8*	3.0*
Production	1	3
Use		
All	3	3
Incidental		
Power plants	3	3
Boilers	5	3
Coke ovens	3	3
Diesel fuel	5	3
Nitrobenzene	3.9*	3.9*
Production	1	1
Use		
Aniline	1	1
Solvent	4	4
Chemical intermediates	4	3
PCBs	2.0*	4.0*
Incidental		
Incinerators	2	4
Phenol	1.2*	2.2*
Production	1	3
Use		
Caprolactam	1	1
Bisphenol A	1	3
Nonylphenol	1	3
Salicylic acid	1	3
Dodecyl phenol	1	4
Phenolic resins	1	4
Adipic acid	1	1
Miscellaneous	5	4

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 38 (Continued)

Chemical	Source Location	Emissions Estimates
Phosgene	1.0*	2.0*
Production	1	2
Use		
TDI	1	2
MDI	1	2
Polycarbonates	5	4
Miscellaneous	5	4
Propylene Oxide	1.0*	2.0*
Production	1	2
Use		
Urethane polyols	1	2
Propylene glycol	1	2
Surfactant polyols	2	4
di/tri-Propylene glycols	1	2
Glycol ethers	2	2
Miscellaneous	5	4
Toluene	3.7*	3.4*
Production	1	1/2/4
Use		
Benzene	1	2
Solvent	5	4
TDI	1	3
Xylenes	1	4
Benzoic acid	1	3
Benzyl chloride	1	3
Vinyl toluene	1	4
Benzaldehyde	2	4
p-Cresol	1	4
Miscellaneous	5	4
Incidental		
Gasoline marketing	3	3

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 38 (Continued)

Chemical	Source Location	Emissions Estimates
Toluene (Continued)		
Incidental		
Gasoline - automobiles	3	3
Gasoline - exhaust	3	3
Coke ovens	3	3
Trichloroethylene	3.1*	3.0*
Production	1	2
Use		
Vapor degreasing	3	3
Solvent	5	4
1,1,1-Trichloroethane	3.6*	3.3*
Production	1	2
Use		
Degreasing	3	3
Chemical intermediate	5	4
Aerosols	5	4
Solvent	5	4
Xylenes (o-, m-, and p- isomers)	4.0*	3.5*
Production		
Catalytic reformate	1	2
Pyrolysis gasoline	1	1
Coal-derived	1	4
Styrene by-product	2	4
Use		
p-Xylene isomer	1	2
o-Xylene isomer	1	4
m-Xylene isomer	1	2
Ethyl benzene	1	4
Solvent	5	4

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 38 (Concluded)

Chemical	Source Location	Emissions Estimates
Xylenes (Continued)		
Use		
Phthalic anhydride	1	3
Terephthalic acid	1	3
Dimethyl terephthalate	1	1
Isophthalic acid	1	1
Incidental		
Gasoline marketing	3	3
Gasoline evaporation - automobiles	3	3
Gasoline exhaust - automobiles	3	3

---

* Composite level of uncertainty based on weighted average of total emissions.

$$E_L(t) = \int_{\Omega_L(t)} p(\bar{x},t)\, dx \qquad (32)$$

where

$$\Omega_L(t) = \{\bar{x} \mid c(\bar{x},t) > L\} \quad .$$

Certain statistics, such as maxima, minima, quantiles, and means could then be derived over a time period from the functions D(t) and $E_L(t)$.

There are various ways in which the estimates obtained in the Human Exposure Project may differ from this idealized computation. Although many of the error components can be analyzed quantitatively, such analysis requires gathering extensive statistics on the population and concentration patterns, a task that is well beyond the resources available to us in this project. The discussion is therefore mostly qualitative. Below, we identify the major error sources.

Sources of Error

Population Count Errors--

The population distribution data base used for the exposure computations is derived from 1970 census counts. These counts are carefully prepared by the Bureau of the Census, but at best are only very accurate estimates. The Bureau has admitted suspicions that in some areas of the country the counts may be too low by significant amounts. However, no comprehensive analysis exists on the degree and distribution of undercounting over the entire United States.

Apart from these suspected undercounts, Minimax found discrepancies between counts in different census data sets. The net difference over the United States is extremely small (0.017 percent) and is probably negligible compared to the undercounting errors. The effect of these population count errors is that exposure and dosage estimates for some regions are too low.

Concentration Pattern Errors--

The concentration patterns used in the exposure computations are obtained through atmospheric dispersion modeling based on known source characteristics and weather patterns at nearby stations. Naturally, any deviations in these estimates from the true pattern directly affect the exposure results.

Additional considerations pertain to concentration pattern estimates for sources not analyzed individually. No statistical data are available on the geographical distribution of sources analyzed by prototype. It is, therefore, very difficult to estimate the exact concentration levels for populations exposed to emissions from more than one such source. The exposure data derived from prototype modeling were based on the assumptions that all sources modeled are isolated sources and that the population in the urban areas exposed to emissions from one source would not be exposed to those from other sources. This assumption is obviously not true everywhere. For example, the total nubmer of trichloroethylene-using open top vapor degreasers in the United States was estimated by HI to be 6,110, and the total land area in urbanized areas is 100,190 km^2, on the average. Therefore, most of the urban population is likely to be exposed to emissions from multiple degreasers; thus, the computations may overestimate the number of people exposed to some concentration but underestimate the dosage received by some individuals. However, for a population in the vicinity of a "major" source (an OTVD or a CVD), the impacts from other sources would be insignificant compared to that from the nearby major source. One might conclude that the exposure estimates are conservative estimates and that the exposure data for the higher concentration levles are more accurate than those for the lower concentration levels. However, the total dosage estimates would not be influenced by the geographical distribution of sources.

Uncertainties in exposure-dosage estimates made with the box model method for area sources include uncertainties of the emissions estimates described in HI's final report, the census population uncertainties as described in Minimax's final report, and uncertainties directly attributable to this method. The last-mentioned uncertainties include the following:

- > Dispersion factors.
  - Representativeness of mean annual wind for the state to each city.
  - Representativeness of neutral atmospheric stability as a long-term mean condition.
- > Time factors.
  - The use of annual average emissions and meteorology.
  - The estimation of 1978 population vehicle totals from data of earlier years.
- > Spatial factors.
  - The use of the Hanna-Gifford model that provides no spatial resolution of concentration patterns.
  - The assumption that population and vehicle density patterns did not change from data base years to 1978.

The effect of each of these factors is to reduce a spectrum of concentration or emissions values (i.e., a set of values ranging from maximum to minimum) to a single, mean value for each city. This may not affect total dosages, but it will lead to underestimation of exposure at high concentrations and overestimation of low concentration exposures.

If the concentration patterns are congruous with the source patterns, time variations of emissions or meteorology would have little effect, because the annual average doses or exposures would average out high and low concentrations in the same proportion at every station. There will, however, be locations where people receive higher or lower exposure-dosage than the mean, even on an annual average basis. Thus, spatial variability appears to be a more significant factor than time variability. The study team explored the possibility of developing a population spectrum as a function of exposure level within individual cities, based on the census population data and land area of all census tracts of a set of representative cities.

Discretizing Errors

Certain errors are introduced into the exposure calculations because each concentration pattern is described by an array of concentrations at only 160 points in the vicinity of the source instead of a continuous function. Similarly, the population distribution is described by a series of "point masses" located at the population centroids of all 1970 census ED/BG. Particularly in less densely populated regions, in which ED/BGs cover relatively large areas, the latter practice may introduce population displacements over sizable distances. Thus, the fractional error is most likely to be large where exposure-dosages are small because of low population density.

We have grouped both of these error sources under the heading of "Discretizing Errors," because both results from replacing continuous functions with discrete approximations for the purpose of reducing the associated computational burden.

Interpolation Error--

Unfortunately, the discrete patterns generated for concentrations and populations generally do not coincide. The exposure program uses interpolation techniques for either of two purposes:

> Compute a concentration value at each ED/BG centroid.
> Apportion the population of each ED/BG among several concentration grid points.

The first technique is used far from the source, where centroids are more densely concentrated than grid points. The second technique is applied near the source, where grid points are more dense than centroids.

Both methods introduce interpolation errors, the severity of which depends on the degree of variability in the concentration and population patterns.

Location Errors--

The relationships between concentrations and populations depend on the accuracy with which the source and ED/BG centroid coordinates are known. Source coordinates are supplied in degrees, minutes, and seconds. For a source in Houston, Texas, for example, a second of longitude represents about 27 meters and a second of latitude represents about 31 meters. ED/BG coordinates are given in degrees to four decimal places. At Houston, .0001 degree of lontitude represents about 11 meters. These figures represent lower bounds on the locational errors, based solely on the precision of the numbers.

We have little information on the actual measurement error in these coordinates. The census documentation we received contained no mention of measurement errors.

In the MED-X validation work, an attempt was made to estimate ED/BG location accuracy by testing whether each ED/BG fell within its corresponding county boundary. About 5.6 percent of the ED/BGs failed the test; only 0.42 percent fell more than 2 km from their county boundaries. Most of these failures are probably due to causes other than centroid location errors, such as concavities in ED/BG boundaries, digitizing errors in the county boundaries, and county boundary changes since 1970. The large amount of "noise" present precluded drawing more definite quantitative estimates from the validation study.

Commuting Pattern Errors--

There are also time-dependent aspects of the exposure problem. The exposure program uses a time-averaged concentration pattern for each source, so that the time dimension is ignored in the computations. If the population distribution were essentially constant over the averaging time period, the resulting estimates would be true averages. However, population distributions are constantly changing as people commute to work, go shopping, and take longer trips. Particularly in urban industrial centers, the shifts in populations and concentrations throughout the day may be highly correlated; thus, the actual exposure may differ considerably from the value obtained by matching time-averaged concentrations with population distributions based on census addresses. Whether the exposure is over- or underestimated depends on whether populations in the vicinity of a source are drained (e.g., because people leave residences near the source for work in an urban center) or are augmented (e.g., because of employment near the source).

A quantitative estimate of this source of error would require a detailed study of commuting patterns for each major SMSA.

Population Growth and Migration Errors--

The final source of error considered here arises from the age of the population estimates, which are based on the 1970 census. Migration and suburban development since April 1970 have affected population distributions around certain sources. The Human Exposure Program does take into account county-level changes in population from 1970 to 1978, but otherwise it leaves the intra-county distributions unaffected. As in the case of commuting patterns, errors arising from migration patterns can be quantified only through detailed studies of the affected regions.

A Simple Model of the Discretizing Error--

Although a full characterization of the uncertainties in the exposure estimates is a very complex job, certain important properties of some of these error sources can be derived from simplified mathematical models.

To analyze the discretizing error with a simple one-dimensional, time-independent model, let c(x) be the concentration and p(x) the population density per unit length. Dosage is given by

$$D = \int c(x)p(x)\,dx \quad . \qquad (33)$$

The discretizing error involves replacing the concentration c(x) with the constant $c(x_0)$ over some ED/BG with centroid at x_0. The Taylor formula for c(x) about x_0 is

$$c(x) = c(x_0) + c'(x_0)\,(x-x_0) + 1/2c''(t_x)\,(x-x_0)^2 \quad , \qquad (34)$$

where t_x is between x and x_0 and depends on x. Then, for this ED/BG,

$$D = \int c(x)p(x)\,dx = c(x_0)P + c'(x_0)\int (x-x_0)p(x)\,dx$$

$$+ 1/2\int c''(t_x)\,(x-x_0)^2\,p(x)\,dx \quad , \qquad (35)$$

where P is the total ED/BG population. The second term is zero, by the definition of x_0 as the population centroid. The third term is the discretizing error in dosage made by computing dosage as the product of the concentration at the centroid and the total population. For a typical concentration pattern, c"(x) is negative along a radial direction near the source and positive farther away. The error term changes sign in the same fashion. This suggests that "discretizing" the concentration pattern leads to a systematic underestimation of dosages at low concentrations and overestimating dosages at high concentrations. The size of the error depends on the value of c"(x) and is, therefore, dependent on the relative locations of sources and ED/BG centroids.

Sensitivity Analysis of Location Errors--

To assess the effect of location errors on exposures and dosages, we reran the computations for Denka Chemical Corporation in Houston, Texas, for the eight possible shifts in the source location obtained by changing the source location by one minute of latitude, longitude, or both, in either direction (N/S or E/W, respectively). Selected results from these runs are shown in Tables 39 and 40. Note that a minute of latitude represents about 1.9 km and a minute of longitude represents about 1.6 km at

TABLE 39. PERCENTAGE OF CHANGE IN DOSAGE FROM BASE CASE RESULTING FROM LOCATION SHIFT

	Changes							
Latitude Shift	+1'	-1'	0	0	+1'	+1'	-1'	-1'
Longitude Shift	0	0	+1'	-1'	+1'	-1'	+1'	-1'
Concentration Level ppb								
10	-54	-92	210	172	71	-71	50	107
1	-44	-6	189	144	23	-75	97	119
0.1	-27	20	65	30	7	-51	48	45
.0	-15	11	40	17	12	-31	29	23
.001	-11	7	33	12	10	-26	22	15
0	-11	7	33	12	10	-26	22	15

Source: Minimax Research Corporation computations.

TABLE 40. PERCENTAGE OF CHANGE IN EXPOSURE FROM BASE CASE RESULTING FROM LOCATION SHIFT

	Changes							
Latitude Shift	+1'	-1'	0	0	+1'	+1'	-1'	-1'
Longitude Shift	0	0	+1'	-1'	+1'	-1'	+1'	-1'
Concentration Level ppb								
10	-60	-90	200	170	70	-70	50	100
1	-35	42	178	127	7	-78	114	132
0.1	-7	9	34	-20	16	-64	27	11
0.01	4	4	12	-6	21	-3	12	-4
.001	3	-4	6	-7	9	-4	1	-12
0	3	-4	6	-7	9	-4	2	-12

Source: Minimax Research Corporation computations.

Houston. These shifts produce very large variations in exposures and dosages estimated for high concentrations. At low concentrations, the dosage variations are still farily large, but exposure counts are relatively stable.

Summary

We have described seven sources of error that can affect the accuracy of the exposure results. Available information was insufficient to support any numerical estimates. Further insight has been gained by studying analytical models and carrying out sensitivity tests, but it is difficult to generalize such results to an entire group of sources.

A fruitful approach in future projects would be to select a small number of sources representing a variety of demographic settings and then to carry out detailed quantitative error analyses for each of these sources, based on information about local conditions. Such a study should provide a better understanding of the error components in human exposure estimates.

REFERENCES

Anderson, G. E., et al. (1977), "Air Quality in the Denver Metropolitan Region: 1974-2000," EPA-908/1-77-002, prepared for the U.S. Environmental Protection Agency, Region VIII, Denver, Colorado, by Systems Applications, Incorporated, San Rafael, California.

Briggs, G. A. (1975), "Lectures on Air Pollutions and Environmental Impact Analyses," American Meteorological Society, Boston, Massachusetts.

Briggs, G. A. (1973), "Diffusion Estimation for Small Emissions," Air Resources Atmospheric Turbulence and Diffusion Laboratory, National Oceanic Atmospheric Administration (NOAA), Oak Ridge, Tennessee.

Briggs, G. A. (1970), "Some Recent Analyses of Plume Rise Observations," Proc. of International Air Pollution Conference, December 1970, Washington, D.C.

Briggs, G. A. (1969), "Plume Rise," USAEC Critical Review Series, TID-25075, Clearinghouse for Federal Scientific and Technical Information.

Burt, E. W. (1977), "Valley Model User's Guide," EPA 450/2-77-018, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Busse, A. D., and J. R. Zimmerman (1973), "User's Guide for the Climatological Dispersion Model," NTIS PB-227346, National Oceanic Atmospheric Association (NOAA), Rockville, Maryland.

CEQ (1977), "Environmental Quality: The Eighth Annual Report of the Council on Environmental Quality," Washington, D.C.

Calvert, J. G., et al. (1975), "Spectroscopic Studies of Photochemical Smog Trace Pollutant Detection," Ohio State University, Columbus, Ohio.

EDF (1977), "Environmental Defense Fund Petition for the Initiation of Rulemaking Proceedings to Establish a Policy Governing the Classification and Regulation of Carcinogenic Air Pollutants Under the Clean Air Act," transmitted by letter to EPA Administrator Costle from Robert Rauch, Staff Attorney, Environmental Defense Fund, Washington, D.C.

EPA (1978), "Administration of the Toxic Substances Control Act: First Annual Report--1977," U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

EPA (1978b), Federal Register, Section 5565, 9 February 1978.

EPA (1977), "User's Manual for Single Source (CRSTER) Model," U.S. Environmental Protection Agency, U.S. Department of Commerce, NTIS PB-271360.

EPA (1976), "Report to U.S. EPA Specialists Conference on the EPA Modeling Guideline," Conference report organized by Argon Laboratory, 22-24 February 1977, Chicago, Illinois.

Gay, B. W., et al. (1976), "Atmospheric Oxidation of Chlorinated Ethylenes," Environ. Sci. Technol., Vol. 10, No. 1, p. 58.

Gifford, F. A., Jr., (1968), "An Outline of Theories of Diffusion in the Lower Layers of the Atmosphere," David H. Slade, ed., Meteorology and Atomic Energy.

Hanna, S. R. (1978), "Diurnal Variation of the Stability Factor in the Simple ATDL Urban Dispersion Model," J. Air Pollut. Control Assoc., Vol. 28, No. 2, pp. 147-150.

Hanna, S. R., and F. A. Gifford (1973), "Modeling Urban Air Pollution," Atmos. Environ., Vol. 7, pp. 131-136.

Hanna, S. R. (1973), "A Simple Dispersion Model for the Analysis of Chemically Reactive Pollutants," Atmos. Environ., Vol. 7, pp. 803-817.

Hanna, S. R. (1971), "A Simple Method of Calculating Dispersion from Urban Area Sources," J. Air Pollut. Control Assoc., Vol. 21, No. 12, pp. 774-777.

Hanst, P. L., J. W. Spence, and M. Miller (1977), "Atmospheric Chemistry of N-Nitroso Dimethylamine," Environ. Sci. Technol., Vol. 11, No. 4, p. 403.

Killus, J. P., et al. (1977), "Continued Research in Mesoscale Air Pollution Simulation Modeling: Volume V--Refinements in Numerical Analysis, Transport, Chemistry, and Pollutant Removal," EF77-142, Systems Applications, Incorporated, San Rafael, California.

Lucas, H. J. (1933), Organic Chemistry, (American Book Company, New York, New York).

Mara, S. J., and S. S. Lee (1978), "Human Exposures to Atmospheric Benzene," EPA-450/3-78-031 Report to the Environmental Protection Agency, Contract 68-01-4314, Stanford Research Institute, Menlo Park, California.

Martin, D. O., and J. A. Tikvart (1968), "A General Atmospheric Diffusion Model for Estimating the Effects on Air Quality of One or More Sources," APCA Paper, presented at the 61st annual APCA meeting, June 1968, St. Paul, Minnesota.

Mitre (1976), "Scoring Organic Air Pollutants," Technical Report 2248.

National Climatic Center (1979), "STAR Tabulations Master List," Asheville, North Carolina.

Pasquill, F. (1971), "Atmospheric Dispersion of Pollution," Q. J. R. Meteorol. Soc., Vol. 97, pp. 369-395.

Pasquill, F. (1970), "The Prediction of Diffusion over an Urban Area," Proc. of the Symposium on Multiple-Source Urban Diffusion, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Pasquill, F. (1961), "The Estimation of the Dispersion of Windborne Material," Met. Mag., Vol. 90, pp 33-49.

Tesche, T. W., and C. S. Burton (1978), "Simulated Impact of Alternative Emissions Control Strategies on Photochemical Oxidants in Los Angeles," EF78-22R, Systems Applications, Incorporated, San Rafael, California.

Turner, D. B. (1970), Workbook of Atmospheric Dispersion Estimates, Office of Air Programs, Publication No. AP-26, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Turner, D. B. (1964), "A Diffusion Model for an Urban Area, Atmospheric Dispersion Estimates," 6th Printing Rev., Government Printing Office, U.S. Environmental Protection Agency, Office of Air Programs, Publ. No. AP-26, Washington, D.C.

Turner, D. B., and J. H. Novak (1978), "User's Guide for RAM," EPA-600/8-78-016a, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Bureau of Census (1979), Statistical Abstract of the United States, 1978 (Government Printing Office, Washington, D.C.).

U.S. Bureau of Census (1978), County and City Data Book, 1977, (Government Printing Office, Washington, D.C.).

U.S. Bureau of Census (1973), County and City Data Book, 1972, (Government Printing Office, Washington, D.C.).

U.S. Federal Highway Administration (1978), "Motor Vehicle Registration," (Government Printing Office, Washington, D.C.).

U.S. Federal Highway Administration (1974), "Motor Vehicle Registrations by Standard Metropolitan Statistical Areas," (Government Printing Office, Washington, D.C.).

Wang, C. C., et al. (1975), "Hydroxyl Radical Concentrations Measured in Ambient Air," Science, Vol. 189, p. 797.

APPENDICES

APPENDIX A-1 ----- Acetaldehyde

APPENDIX A-2 ----- Acrolein

APPENDIX A-3 ----- Allyl Chloride

APPENDIX A-4 ----- Benzyl Chloride

APPENDIX A-5 ----- Beryllium

APPENDIX A-6 ----- Carbon Tetrachloride

APPENDIX A-7 ----- Chlorobenzene (p-Dichlorobenzene and o-Dichlorobenzene)

APPENDIX A-8 ----- Chloroform

APPENDIX A-9 ----- Chloroprene

APPENDIX A-10 ----- Cresol

APPENDIX A-11 ----- Dimethylnitrosamine

APPENDIX A-12 ----- Dioxin

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APPENDIX A-14 ----- Ethylene Oxide

APPENDIX A-15 ----- Formaldehyde

APPENDIX A-16 ----- Hexachlorocylopentadiene

APPENDIX A-17 ----- Manganese

APPENDIX A-18 ----- 1,1,1-Trichloroethane (Methyl Chloroform)

APPENDIX A-19 ----- Methylene Chloride

APPENDIX A-20 ----- Nitrosomorpholine

APPENDIX A-21 ----- Nickel

APPENDIX A-22 ----- Nitrobenzene

APPENDIX A-23 ----- PCB

APPENDIX A-24 ----- Phenol

APPENDIX A-25 ----- Phosgene

APPENDIX A-26 ----- Propylene Oxide

APPENDIX A-27 ----- Toluene

APPENDIX A-28 ----- Trichloroethylene

APPENDIX A-29 ----- Xylene

The following three pages were located at the beginning of each appendix. In order to reduce the reproduction cost, all duplications of these pages have been removed. Thus, each appendix will begin on page four.

Each chemical was studied as one of a set of 35 chemicals. A complete description of the program is given in the parent document to this attachment. The table of contents of the parent report is presented as Figure 1 here. Specific questions that the reader may have about presentations in this attachment are most probably addressed in the relevant section or sections as described in Figure 1.

This attachment consists of the following elements:

- > A table of physical and chemical properties of the chemical.
- > A summary of emission sources, modes, and rates.
- > A map showing major, specific point sources.
- > Input parameters for dispersion calculations.
- > Exposure/dosage tables for each type of source analyzed and a summary for all sources.
- > A reference list for the emissions study.

A few definitions--described more completely in the main text--are presented here as an aid to the reader.

- > EXPOSURE - The number of people in the United States estimated to experience annual average atmospheric concentrations equal to or greater than the stated level.
- > DOSAGE - The sum over the population of the product of concentration (μgm/m^3), times number of people exposed at that concentration. This is a potential concentration, and does not represent material actually ingested or absorbed into body tissues.
- > EMISSIONS ANALYSIS - A review by one or more of various methods including surveys of literature or state and federal data, communication with, or visits to, staff of the operator of the sources to determine sources and source locations, and to estimate
  - emission rates-adjusted to 1978

- type of source (e.g. chimney, vent, open surface, etc).

> DISPERSION ANALYSIS - Use of a computer program to compute annual average concentration patterns given wind, turbulence and emissions data.

> POPULATION ANALYSIS - Use of a computer program to extract site-specific population patterns at the finest resolution available from U.S. Census Bureau 1970 census files. Populations are scaled to 1978 levels.

> SOURCE TYPE - Three source types are defined:
  - Major, specific point sources, each emitting a significant fraction of the total emissions of a studied chemical. These sources are treated using parameters appropriate to each specific source.
  - General point sources - other point sources warranting a detailed dispersion analysis but which are members of a group of sources too numerous to treat individually. For such sources, a prototype analysis is done, and results are multiplied by the estimated number of sources.
  - Area Sources - sources which are so small and numerous that their concentration patterns are inseparable. Such sources are treated as emissions per unit area over identified areas.

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APPENDICES

APPENDIX A-1 ----- Acetaldehyde

ACETALDEHYDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 75-07-0

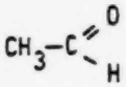
Synonyms: Acetic Aldehyde; Ethyl Aldehyde; Ethanal

Chemical Formula

Molecular Weight: 44.05

Molecular Formula: C_2H_4O,

Molecular Structure:



$CH_3{-}C{\overset{O}{\underset{H}{\lessgtr}}}$

Chemical and Physical Properties

Physical State at STP: Liquid - flammable, pungent odor

Boiling Point: 20.8°C at 760mm

Melting Point: -121°C

Density: 0.7834 at 18°C/4°C

Vapor Pressure: 923 Torrs at 25°C

Vapor Density: 1.52

Solubility: Infinite (hot H_2O)

Log Partition Coefficient (Octanol/H_2O): 0.43

Atmospheric Reactivity

Transformation Products: Peroxyacetyl Nitrate; Formaldehyde

Reactivity Toward OH·: 4 x Butane

Reactivity Toward O_3: No reaction

Reactivity Toward Photolysis: ≈ 0.5 x Formaldehyde

Major Atmospheric Precursors: Hydrocarbons (C_3 +)

Formation Reactivity: Equilibrium concentration ≈ 5% NMHC

I. SOURCES

A. PRODUCTION

Acetaldehyde (C_2H_4O) is produced by ethylene oxidation processes, such as the Wacker process, or by vapor phase oxidation and dehydrogenation of ethanol. The latter method has declined rapidly since the ethylene oxidation facilities have come on-stream. Publicker is the only company that uses the ethanol process.[1]

In the ethanol process, ethanol vapors and preheated air are mixed. The exit gases, containing ethanol and acetaldehyde, are scrubbed and the solution is rectified in a column to produce acetaldehyde. In the direct oxidation of ethylene, air or oxygen can be used. A water solution of cupric chloride and a small amount of palladium chloride is generally used as a catalyst. The gaseous reaction mixture containing steam and unreacted ethylene in addition to reaction product gases goes to a water scrubber, where acetaldehyde is removed in solution.[1]

There are currently four companies at five locations that produce acetaldehyde in the United States. The locations of the plants and the 1978 estimated capacity and production levels for each site are shown in Table 1-1.[1,2] An estimated 1000 million lb of acetaldehyde was produced in 1978.[1,2]

B. USES

Acetaldehyde is used exclusively as a chemical intermediate to produce other chemicals. The largest end-use is in acetic acid manufacture, which accounts for an estimated 690 million lb of production. The second largest end-use is for peracetic acid production, which consumed an estimated 100 million lb in 1978. Other uses of acetaldehyde include pentaerythritol (80 million lb), pyridines (40 million lb), glyoxal (40 million lb), 1,3-butylene glycol (20 million lb), and miscellaneous uses (remaining 30 million lb). There were no reported exports of acetaldehyde in 1978. Acetaldehyde end-uses are summarized in Table 1-2.[1,2]

Acetic acid is produced by two companies at three locations by the catalytic oxidation of acetaldehyde. Source locations are shown in Table 1-3.[3,4]

Table 1-1. Acetaldehyde Producers[a]

Company[b]	Location	1978 Capacity (10^6 lb/yr)	1978 Production[c] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Celanese	Bay City, TX	300	204	28 51 45/96 01 00
	Clear Lake, TX	600	408	29 37 17/95 03 51
Texas Eastman	Longview, TX	500	340	32 25 55/94 41 06
Publicker Industries	Philadelphia, PA	65	44	39 53 30/75 12 18
Shell Chemical	Norco, LA	5	4	30 00 11/90 23 42
Total		1470	1000	

[a] See refs. 1 and 2.

[b] Union Carbide shut down 200 million lb of capacity at Institute and S. Charleston, WV, in the first quarter of 1978.

[c] Total production distributed over individual sites based on site capacity compared to total industry capacity.

Table 1-2. 1978 Acetaldehyde End-Use Distribution*

End-Use	Usage (%)	Acetaldehyde Use (million lb/yr)
Acetic acid	69	690
Peracetic acid	10	100
Pentaerythritol	8	80
Pyridenes	4	40
Glyoxal	4	40
1,3-Butylene glycol	2	20
Miscellaneous	3	30
Total	100	1000

*See refs. 1 and 2.

Table 1-3. Acetic Acid Producers[a]

Company	Location	1978 Acetic Acid Capacity (10^6 lb/yr)	1978 Acetaldehyde Usage[b] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Celanese	Bay City, TX	110	68	28 51 45/96 01 00
	Clear Lake, TX	600	373	29 37 17/95 03 51
Tennessee Eastman	Kingsport, TN	400	249	36 31 27/88 32 29
Total		1110	690	

[a] See refs. 3 and 4.

[b] Total acetaldehyde usage distributed over all three sites based on acetic acid capacity.

Peracetic acid is manufactured by the liquid-phase catalytic oxidation of acetaldehyde at three sites in the United States. Source locations are shown in Table 1-4.[3]

Pentaerythritol is produced by the aldol condensation of acetaldehyde and formaldehyde in the presence of lime or caustic at ambient temperature and pressure. The four manufacturing sites are shown in Table 1-5.[3,5]

Synthetic pyridenes are produced as a co-product with beta-picoline by the vapor phase reaction of acetaldehyde, ammonia, and formaldehyde by two companies in the United States. Source locations are shown in Table 1-6.[3,6]

Glyoxal is produced by two companies by the nitric acid oxidation of acetaldehyde in an autoclave at two locations as shown in Table 1-7.[3]

1,3-Butylene glycol is produced by the catalytic hydrogenation of acetaldol which is made by the liquid-phase condensation of acetaldehyde. The three companies at three sites which produce 1,3-butylene glycol are shown in Table 1-8.[3]

II. EMISSION ESTIMATES

A. PRODUCTION

Acetaldehyde emissions from production sites are presented in Table 1-9.[7,8,9,10,11] Total estimated emissions from these sites for 1978 were 270,000 lb. Emission factors, derived from state files, used to develop process, storage, and fugitive emission estimates are shown in Table 1-9. Process vent emissions originate primarily from the off-air absorber vents. Other associated emissions would include ethylene and ethane. Storage emissions represent the losses from both working and final product storage tanks. Fugitive emissions are those which result from plant equipment leaks. For the purpose of this report, the emissions of acetaldehyde from the ethanol process used by Publicker were assumed to be the same (emission factor) since no data were available from that site.

Vent parameter data for the production sites[11] as well as the end-users are shown in Table 1-10.

Table 1-4. Peracetic Acid Producers[a]

Company	Location	1978 Peracetic Acid Capacity (million lb)	1978 Acetaldehyde Used (million lb)[b]	Geographic Coordinates Latitude/Longitude
FMC	Buffalo, NY	NA[c]	33.33	42 59 10/78 50 30
High Point Chemical	High Point, NC	NA	33.33	35 59 10/80 00 30
Union Carbide	Taft, LA	NA	33.33	29 58 00/90 27 00
Total		NA	100.00	

[a] See ref. 3.

[b] Total acetaldehyde used distributed evenly over all three sites in the absence of capacity data.

[c] Not available.

Table 1-5. Pentaerythritol Producers[a]

Company	Location	1978 Pentaerythritol Capacity (10^6 lb/yr)	1978 Acetaldehyde Used[b] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Celanese	Bishop, TX	75	33	27 34 06/97 49 27
Hercules	Louisiana, MO	47	21	39 26 24/91 03 37
IMC (CSC)	Seiple, PA	25	11	40 38 12/75 31 58
Perstorp AB	Toledo, OH	35	15	41 43 10/83 31 28
Total		182	80	

[a] See refs. 3 and 5.

[b] Total acetaldehyde usage distributed over all four sites based on pentaerythritol capacity.

Table 1-6. Pyridenes Producers[a]

Company	Location	1978 Pyridene Capacity[b] (10^6 lb/yr)	1978 Production[c] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Nepara Chemical	Harriman, NY	>25	17	41 16 45/74 08 24
Reilly Tar & Chemical	Indianapolis, IN	35	23	39 42 00/86 14 00
Total		>60	40	

[a] See refs. 3 and 6.

[b] Capacity includes pyridenes, picolines, and pyridene derivatives.

[c] Total acetaldehyde usage distributed over both sites based on pyridenes' capacity.

Table 1-7. Glyoxal Producers[a]

Company	Location	1978 Glyoxal Capacity (million lb)	1978 Estimated Acetaldehyde Used[b] (million lb)	Geographic Coordinates Latitude/Longitude
American Cyanamide	Charlotte, NC	NA[c]	20	35 12 16/80 50 32
Union Carbide	Taft, LA	NA	20	29 58 00/97 27 00
Total		NA	40	

[a] See ref. 3.

[b] Total acetaldehyde used distributed equally over both sites in the absence of capacity data.

[c] Not available.

Table 1-8. 1,3-Butylene Glycol Producers[a]

Company	Location	1978 1,3-Butylene Glycol Capacity (million lb)	1978 Acetaldehyde Used (million lb)	Geographic Coordinates Latitude/Longitude
Celanese	Bishop, TX	NA[c]	6.67	27 34 06/97 49 27
Eastman	Rochester, NY	NA	6.67	43 12 01/77 37 58
Mallinckrodt	Lodi, NJ	NA	6.67	40 52 56/74 05 46
Total		NA	20.00	

[a] See ref. 3.

[b] Total actaldehyde used distributed evenly over all three sites in the absence of capacity data.

[c] Not available.

Table 1-9. Acetaldehyde Emissions from Production Sites

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Celanese	Bay City, TX	46,510	5,915	2,650	55,080	0.79
	Clear Lake, TX	93,025	11,830	5,305	110,160	1.59
Tennessee Eastman	Longview, TX	77,520	9,860	4,420	91,800	1.32
Publicker Industries	Philadelphia, PA	10,030	1,275	570	11,880	0.17
Shell Chemical	Norco, LA	910	115	50	1,080	0.02
Total		228,000	29,000	13,000	270,000	

[a] Based on the following emission factors (lb acetaldehyde emitted per lb produced). See refs. 7, 8, 9, 10, and 11.

Process	0.000228	B - (derived from state air emission files)
Storage	0.000029	B - (derived from state air emission files)
Fugitive	0.000013	B - (derived from state air emission files)
Total	0.000270	

[b] Based on 8760 hr/yr operation.

Table 1-10. Acetaldehyde Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Distribution Area (ft X ft)
Production						
Process	4	36	1.0	70		
Storage	3	24	0.17	80		
Fugitive						400 X 800
Acetic acid						
Process	4	30	1.2	75	190	
Storage	4	24	0.17	80		
Fugitive						300 X 300
Peracetic acid						
Process	1	30	1.0	80	110	
Storage	2	24	0.17	80		
Fugitive						300 X 300
Pentaerythirtol						
Process	3	140	1.5	140	175	
Storage	2	20	0.33	70		
Fugitive						100 X 200
Pyridenes						
Process	1	30	0.5	100	10	
Storage	2	16	0.17	80		
Fugitive						100 X 200

Table 1-10. (Continued)

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Distribution Area (ft X ft)
Glyoxal						
Process	2	20	0.08	70	5	
Storage	2	16	0.17	70		
Fugitive						100 X 100
1,3-Butylene glycol						
Process	2	20	0.08	65	44	
Fugitive						100 X 100

Note: building cross-section for production and end-uses - 50 m^2.

B. USES

Emission estimates for the end-users of acetaldehyde in 1978 are summarized in Table 1-11. They are based on the emission factors tabulated in Table 12.

Acetaldehyde emissions from acetic acid production were estimated to have been 2,801,550 lb. Other associated emissions would include acetic acid and ethyl acetate.

Acetaldehyde emissions from peracetic acid production were estimated to have been 450,000 lb. Other associated emissions would include ethyl acetate and peracetic acid.

Pentaerythritol production contributed an estimated 688,000 lb of acetaldehyde. Other associated emissions would include formaldehyde, ammonia, and pentaerythritol.

Pyridenes manufacture release an estimated 300,000 lb of acetaldehyde. Other emission components include picoline, formaldehyde, and pyridene.

Glyoxal production contributed an estimated 180,000 lb of acetaldehyde. Other associated emissions besides blyoxal are unknown.

1,3-Butylene glycol manufacture contributed 27,000 lb of acetaldehyde emissions. Other associated emissions include ethanol, dioxane, and 1,3-butylene glycol.

Miscellaneous uses of acetaldehyde were estimated to have contributed 153,900 lb. These uses are too diverse and numerous to specify or location. Emissions were estimated by taking a weighted average of all the other acetaldehyde end-uses and multiplying by the 30 million lb used.

The total nationwide emissions of acetaldehyde in 1978 were estimated to have been 4,870,450 lb. A tabulation of the losses is shown in Table 1-13.

Table 1-11. Acetaldehyde Emissions from End-Users

Company	Location	End-Use	Emissions (lb/yr) Process	Storage	Fugitive	Total Emissions[a] (lb/yr)	(g/sec)[b]
Celanese	Bay City, TX	Acetic acid	180,880	22,440	10,200	213,520	3.07
	Clear Lake, TX	Acetic acid	992,180	123,090	55,950	1,171,220	16,86
Eastman	Kingsport, TN	Acetic acid	1,197,690	151,890	67,230	1,416,810	20.40
FMC	Buffalo, NY	Peracetic acid	135,000	7,330	7,670	150,000	2.16
High Point	High Point, NC	Peracetic acid	135,000	7,330	7,670	150,000	2.16
Union Carbide	Taft, LA	Peracetic acid	135,000	7,330	7,670	150,000	2.16
Celanese	Bishop, TX	Pentaerythritol	241,230	29,040	13,530	283,800	4.09
Hercules	Louisiana, MO	Pentaerythritol	153,510	18,480	8,610	180,600	2.60
IMC	Seiple, PA	Pentaerythritol	80,410	9,680	4,510	94,600	1.36
Perstorp	Toledo, OH	Pentaerythritol	109,650	13,200	6,150	129,000	1.86
Nepara	Harriman, NY	Pyridenes	108,460	10,880	8,160	127,500	1.84
Reilly	Indianapolis, IN	Pyridenes	146,740	14,720	11,040	172,500	2.48
American Cyanamide	Charlotte, NC	Glyoxal	81,000	4,400	4,600	90,000	1.30
Union Carbide	Taft, LA	Glyoxal	81,000	4,400	4,600	90,000	1.30
Celanese	Bishop, TX	1,3-Butylene glycol	8,135	0	865	9,000	0.13
Eastman	Rochester, NY	1,3-Butylene glycol	8,135	0	865	9,000	0.13
Mallinckrodt	Lodi, NJ	1,3-Butylene glycol	8,135	0	865	9,000	0.13
Total			3,802,155	424,210	220,185	4,446,550	

[a] Derived from the emission factors shown in Table 12.

[b] Based on 8760 hr/yr operation.

Table 1-12. Acetaldehyde End-Use Emission Factors

End-Use	Process	Derivation[a]	Storage	Derivation	Fugitive	Derivation	Total
Acetic acid - Celanese	0.00266	B	0.00033	B	0.00061	B	0.00314[b]
Acetic acid - Eastman	0.00481	B	0.00015	B	0.00027	B	0.00569[c]
Peracetic acid	0.00405	B	0.00022	B	0.00023	B	0.00450[d]
Pentaerythritol	0.00731	C	0.00088	C	0.00041	C	0.00860[e]
Pyridenes	0.00638	C	0.00004	C	0.00048	C	0.00750[e]
Glyoxal	0.00405	D	0.00022	D	0.00023	D	0.00450[f]
1,3-Butylene glycol	0.00122	B	0	B	0.00013	B	0.00013[g]

[a] A - Basis: site visit data
B - Basis: state emission files
C - Basis: published literature
D - Basis: Hydroscience estimate

[b] See refs. 7 and 8.

[c] See ref. 10.

[d] See ref. 12.

[e] See ref. 13.

[f] Hydroscience estimate.

[g] See ref. 14.

Table 1-13. 1978 Acetaldehyde Nationwide Emissions

Source	Nationwide Emissions (lb/yr)
Production	270,000
Acetic acid	2,801,550
Peracetic acid	450,000
Pentaerythritol	688,000
Pyridenes	300,000
Glyoxal	180,000
1,3-Butylene glycol	27,000
Miscellaneous*	137,400
Total	4,853,950

*Based on a weighted average of emission factors for other user categories. Factor: 0.00458 lb lost/lb used.

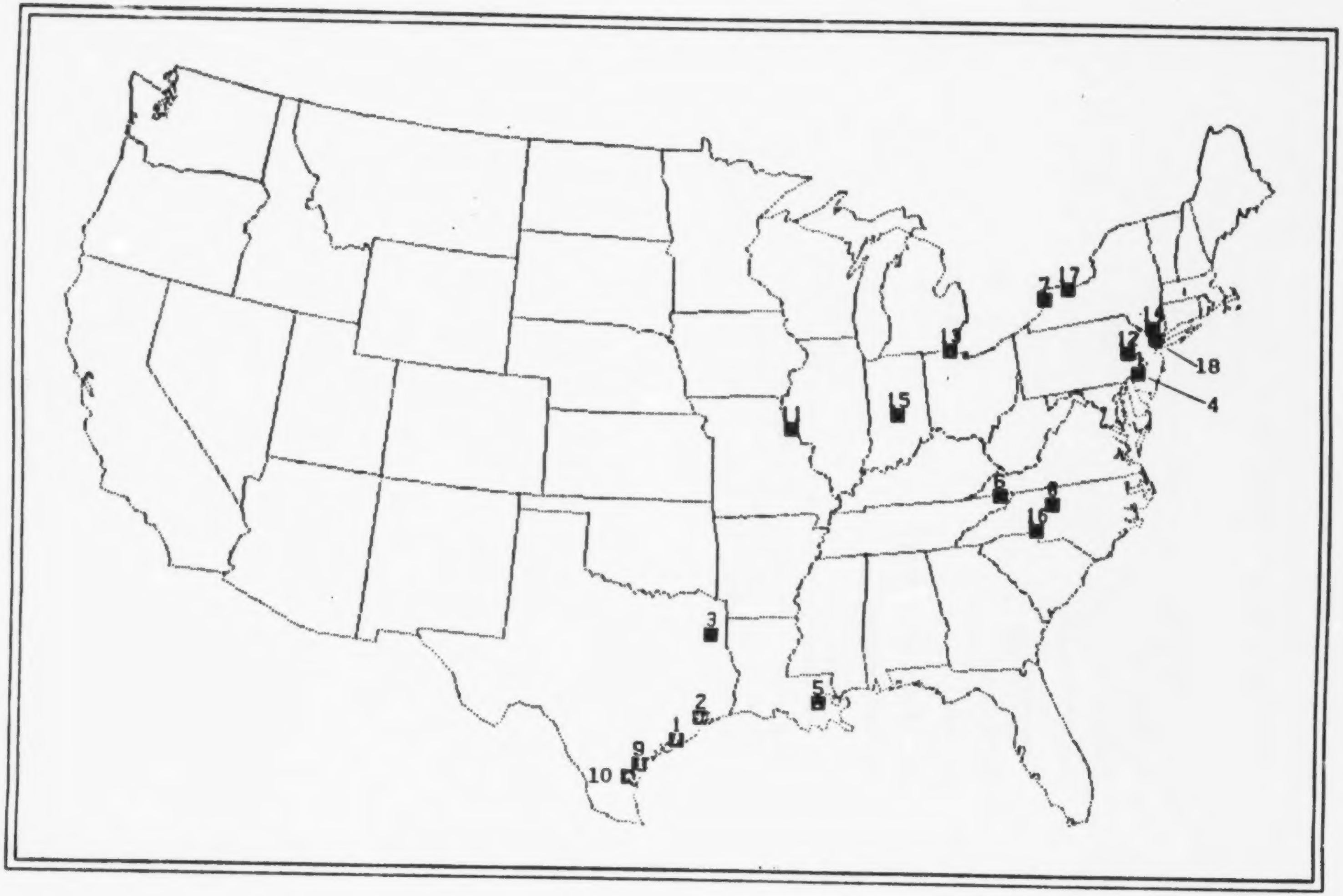

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FIGURE 1-1. SPECIFIC POINT SOURCES OF ACETALDEHYDE EMISSIONS

TABLE 1-14. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF ACETALDEHYDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	CELANESE	BAY CITY, TX	28 51 45	96 01 00	12923	1	1 2	.669744 2.604672	.085176 .323136	.038160 .146880
2	CELANESE	CLEAR LAKE, TX	29 37 17	95 03 51	12906	1	1 2	1.339560 14.287392	.170352 1.772496	.076392 .805680
3	EASTMAN KODAK	LONGVIEW, TX	32 25 55	94 41 06	13972	2	1	1.116288	.141984	.063648
4	PUBLICKER	PHILADELPHIA, PA	39 53 30	75 12 18	13739	2	1	.144432	.018360	.008208
5	SHELL	NORCO,LA	30 00 11	90 23 42	12958	2	1	.013104	.001656	.000720
6	EASTMAN KODAK	KINGSPORT, TN	36 31 41	82 12 22	13877	3	2	17.246736	2.187216	.968112
7	FMC	BUFFALO, NY	42 59 10	78 50 30	14747	4	3	1.944000	.105552	.110448
8	HIGHPOINT	HIGH POINT, NC	35 59 10	80 00 37	93807	4	3	1.944000	.105552	.110448
9	UNION CARBIDE	TAFT, LA	27 58 00	97 27 00	13970	5	3 6	1.944000 1.166400	.105552 .063360	.110448 .066240
10	CELANESE	BISHOP, TX	27 34 06	97 49 27	12925	6	4 7	3.473712 .117144	.418176 0.	.194832 .012456
11	HERCULES	LOUISIANA, MO	39 26 24	91 03 37	93989	7	4	2.210544	.266112	.123984
12	IMC	SEIPLE, PA	40 38 21	75 31 38	14737	7	4	1.157904	.139392	.064944
13	PERSTORP	TOLEDO, OH	41 43 10	83 31 28	94830	7	4	1.578960	.190080	.088560
14	NEPARA	HARRIMAN, NY	41 16 40	74 08 24	14757	8	5	1.561824	.155520	.117504
15	REILLY TAR	INDIANAPOLIS, IN	39 42 00	86 14 00	93819	8	5	2.113056	.211968	.158976
16	AMER CYANAMID	CHARLOTTE,NC	35 12 16	80 50 32	13881	9	6	1.166400	.063360	.066240
17	EASTMAN KODAK	ROCHESTER, NY	43 12 01	77 37 58	14717	10	7	.117144	0.	.012456
18	MALLINCKRODT	LODI, NJ	40 52 56	74 05 46	94741	10	7	.117144	0.	.012456

TABLE 1-14 (Concluded)

* Plant Types:

Type 1: Plant produces acetaldehyde and acetic acid

Type 2: Plant produces acetaldehyde

Type 3: Plant produces acetic acid

Type 4: Plant procudes peracetic acid

Type 5: Plant produces peracetic acid and glyoxal

Type 6: Plant produces pentaerythirtol and 1, 3-butylene glycol

Type 7: Plant produces pentaerythirtol

Type 8: Plant produces pyridenes

Type 9: Plant produces glyoxal

Type 10: Plant produces 1, 3-butylene glycol

† Source Types:

Type 1: Acetaldehyde production

Type 2: Acetic acid production

Type 3: Peracetic acid production

Type 4: Pentaerythirtol production

Type 5: Pyridenes production

Type 6: Glyoxal production

Type 7: 1, 3-butylene glycol

TABLE 1-15. EMISSIONS PARAMETERS FOR SPECIFIC POINT SOURCES OF ACETALDEHYDE

Source Type	Emissions Category	Vent Height (m)	Building Cross Section (m^2)	Vent Diameter (m)	Vent Velocity (m/sec)	Vent Temperature (°k)
Acetaldehyde production	Process	10.8	50	0.3	--	--
	Storage	7.2	50	0.05	--	--
	Fugitive	0	50	--	--	--
Acetic acid production	Process	9.0	50	0.36	57	--
	Storage	7.2	50	0.05	--	--
	Fugitive	0	50	--	--	--
Peracetic acid production	Process	9.0	50	0.3	33	--
	Storage	7.2	50	0.05	--	--
	Fugitive	0	50	--	--	--
Pentaerythirtol production	Process	42	50	0.45	52	333
	Storage	4.8	50	0.10	--	--
	Fugitive	0	50	--	--	--
Pyridenes production	Process	9	50	0.15	3	311
	Storage	4.8	50	0.05	--	--
	Fugitive	0	50	--	--	--
Glyoxal production	Process	6	50	0.02	1.5	--
	Storage	4.8	50	0.05	--	--
	Fugitive	0	50	--	--	--

TABLE 1-15 (Concluded)

Source Type	Emission Category	Vent Height (m)	Building Cross Section (m^2)	Vent Diameter (m)	Vent Velocity (m/sec)	Vent Temperature (°k)
1,3-Butylene glycol production	Process	6	50	0.02	13	--
	Fugitive	0	50	--	--	--

TABLE 1-16. EXPOSURE AND DOSAGE OF ACETALDEHYDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
1,000	2	2,160
500	5	4,650
250	13	7,210
100	28	9,430
50	83	13,200
25	317	21,100
10	1,835	44,600
5	5,579	70,700
2.5	14,296	99,400
1	41,267	140,000
0.5	88,591	173,000
0.25	169,691	201,000
0.1	418,584	239,000
0.05	836,572	268,000
0.25	1,574,194	294,000
0.01	3,170,624	320,000
0.005	4,132,507	327,000
0.0025	5,448,040	
$2.12X10^{-12}$*	12,423,341	337,000

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 1-17. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF ACETALDEHYDE

Parameter	Value
Daytime decay rate (K_d)	7.3×10^{-5} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H	0
Nationwide nonheating stationary source emissions (E_N)	1.98 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 1-18. ACETALDEHYDE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.010000	446952	4759.0	0.	100.0	0.	100.0	0.	0.
.005000	505140	5263.7	0.	100.0	0.	100.0	0.	0.
.002500	9149730	37317.9	0.	100.0	0.	100.0	0.	0.
.001000	35088457	75128.7	0.	100.0	0.	100.0	0.	0.
.000500	89470782	110094.3	0.	100.0	0.	97.2	1.2	1.6
.000250	135836014	127481.4	0.	100.0	0.	94.0	2.6	3.4
0.	158679135	131504.0	0.	100.0	0.	92.4	2.8	4.8

TABLE 1-19. EXPOSURE AND DOSAGE SUMMARY OF ACETALDEHYDE

	Population Exposed (persons)				Dosage [(μg/m^3)·persons]			
Concentration Level (μg/m^3)	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
1,000	2	0	0	2	2,160	0	0	2,160
500	5	0	0	5	4,650	0	0	4,650
256	13	0	0	13	7,210	0	0	7,210
100	28	0	0	28	9,430	0	0	9,430
50	83	0	0	83	13,200	0	0	13,200
25	317	0	0	317	21,100	0	0	21,100
10	1,835	0	0	1,835	44,600	0	0	44,600
5	5,579	0	0	5,579	70,700	0	0	70,700
2.5	14,296	0	0	14,296	99,400	0	0	99,400
1	41,267	0	0	41,267	140,000	0	0	140,000
0.5	88,591	0	0	88,591	173,000	0	0	173,000
0.25	169,691	0	0	169,691	201,000	0	0	201,000
0.1	418,584	0	0	418,584	239,000	0	0	239,000
0.05	836,572	0	0	836,572	268,000	0	0	268,000
0.025	1,574,194	0	0	1,514,194	294,000	0	0	294,000
0.01	3,170,624	0	446,952	3,617,576	320,000	0	4,760	324,760
0.005	4,132,507	0	505,140	4,637,647	327,000	0	5,260	332,260
0.0025	5,448,040	0	9,149,730	14,597,770	331,000	0	37,300	368,300
0.001	--	0	35,008,457	--	--	0	75,100	--
0.0005	--	0	89,470,782	--	--	0	110,000	--
0.00025	--	0	135,836,014	--	--	0	127,000	--
0	12,423,341	0	158,679,135	--	337,000	0	132,000	469,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. A. K. Rafie and S. L Soder, "Acetaldehyde," Chemical Economics Handbook, p. 601.5020F, Stanford Research Institute, Menlo Park, CA (March 1979).

2. "Chemical Products Synopsis on Acetaldehyde," Mannsville Chemical Products, October 1976.

3. 1978 Directory of Chemical Producers, United States, p. 415, Stanford Research Institute, Menlo Park, CA.

4. A. K. Rafie, S. L. Soder, "Acetic Acid," p. 602.5020E, Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (April 1977).

5. "Chemical Products Synopsis on Pentaerythritol," Mannsville Chemical Products, (December 1977).

6. "Chemical Products Synopsis on Pyridines Synthetic," Mannsville Chemical Products, (December 1977).

7. Texas Air Control Board 1975 Emissions Inventory Questionnaire, Celanese Chemical Co., Bay City, Texas.

8. Texas Air Control Board 1975 Emissions Inventory Questionnaire, Celanese Chemical Co., Clear Lake, Texas.

9. Texas Air Control Board 1975 Emissions Inventory Questionnaire, Texas Eastman Co., Longview, Texas.

10. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, Volume I, prepared for Environmental Protection Agency, Office of Air and Water Standards, Research Triangle Park, NC, by J. W. Pervier, et al., Houdry Division, Air Products and Chemicals, Inc., Marcus Hook, PA, January 1974 EPA-450/3-73-005a.

11. Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry, Acetaldehyde Abbreviated Product Report, prepared for Office of Air Quality Planning and Standards, Environmental Protection Agency, Research Triangle Park, North Carolina, by R. J. Lovell, Hydroscience, Inc., January 1979.

12. Louisiana Air Board, 1975 Emission Inventory Questionnaire, Union Carbide, Taft, LA.

13. Special Project Report "Petrochemical Plant Sites" prepared for Industrial Pollution Control Division, Industrial Environmental Research Laboratory, Environmental Protection Agency, Cincinnati, Ohio, by Monsanto Research Corporation, Dayton, Ohio, April 1976.

14. Texas Air Control Board 1975 Emissions Inventory Questionnaire, Celanese Chemical Co., Bishop, Texas.

APPENDIX A-2 ----- Acrolein

ACROLEIN CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 107-02-8

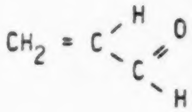
Synonyms: 2-Propenal; Acrylic Aldehyde; Allyl Aldehyde; Acrylaldehyde; Acraldehyde

Chemical Formula

Molecular Weight: 56.06

Molecular Formula: C_3H_4O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - flammable, pungent odor

Boiling Point: 52.5°C

Melting Point: -86.95°C

Density: 0.8410 at 20°C/4°C

Vapor Pressure: 288.2 mm at 25°C

Vapor Density: 1.94

Solubility: very soluble, (400 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products: Formaldehyde

Reactivity Toward OH·: 1/2 Propylene

Reactivity Toward O_3: 1/2 Propylene

Reactivity Toward Photolysis: ≈ 5 x Formaldehyde

Major Atmospheric Precursors: N/A

Formation Reactivity: N/A

A. ACROLEIN

All acrolein is currently produced in the United States by the direct oxidation of propylene.[1] The specific processes vary significantly, depending primarily on the by-product distribution desired and on the end-use requirements.[3,4]

Acrolein is currently produced by four companies at four locations in the United States.[1] The plant locations and the 1978 capacity and estimated production level for each plant are shown in Table 2-1. An estimated 350 million lb of arcrolein was produced in 1978.[5]

The largest end-use of acrolein is as an unisolated intermediate in the production of acrylic acid and its derivatives.[1] This end-use consumed an estimated 87% of production in 1978 amounting to 308 million lb.[5]

The end-uses of refined, or isolated, acrolein are small compared to its use as an unisolated intermediate in acrylic acid production. Synthetic glycerin consumed an estimated 24 million lb (7% of total acrolein production) in 1978.[5] Refined acrolein is also used in the manufacture of methionine and methionine hydroxy analogue (poultry feed supplements) which consumes 20 million lb. Miscellaneous applications consume the remaining 2 $\bar{M}$ lb and include 1,2,6-hexanetriol (a humectant used in flexible polyurethane foam manufacture), glutaraldehyde (used in leather tanning), and others.[1] Total consumption of acrolein in chemical intermediate applications is estimated to have been 22 million lb (6%) in 1978. End-uses are summarized in Table 2-2.[5]

Table 2-1. Production of Allyl Chloride, Epichlorohydrin, and Acrolein[a]

Source	Location	1978 Estimated Production[b] (M̄ lb)			1978 Estimated Capacity (M̄ lb)			Geographic Coordinates
		Allyl Chloride	Epichlorohydrin	Acrolein	Allyl Chloride	Eqichlorohydrin	Acrolein	Latitude/Longitude
Dow Chemical Co.	Freeport, TX	176	166		265	250		28 59 30/95 23 35
Shell Chemical Co.	Deer Park, TX	77	73		117	110		29 42 55/95 07 34
Shell Chemical Co.	Norco, LA	77	73	24[c]	117	110	55[c]	30 00 11/90 23 42
Union Carbide Corp.	Taft, La			22[c]			60[c]	29 58 00/90 27 00
Celanese Corp.	Clear Lake, TX			89[d]			167[d]	29 37 17/95 03 51
Rohm and Haas Co.	Deer Park, TX			146[d]			273[d]	29 43 30/95 06 15
Union Carbide Corp.	Taft, LA			73[d]			137[d]	29 58 00/90 27 00
Total		330	312	354	499	470	692	

[a] See refs 1 and 2.

[b] The distribution of production for each producer is determined by the ratio of total U.S. production to total U.S. capacity as compared to individual plant capacity.

[c] Isolated acrolein.

[d] Acrolein produced as an unisolated intermediate in the propylene oxidation process for acrylic acid and derivitives.

Table 2-2. 1978 Acrolein Consumption by End-Use[a]

End-Use	Usage (%)	End-Use Consumption ($\bar{M}$ lb)
Acrylic acid and esters[b]	87	308
Glycerin	7	24
Methionine and methionine hydroxy analogue	6	20
Miscellaneous[c]	>1	2
Total	100	354

[a] See refs. 1 and 2.

[b] Acrolein produced as an unisolated intermediate in the propylene oxidation process used to produce acrylic acid and esters.

[c] Includes glutaraldehyde, 1,2,6-hexane triol and others.

Estimated production losses are shown in Table 2-3 for each of the four producing locations. Total emissions of acrolein from production faclities are estimated to have been 76,300 lb in 1978. In the production of acrylic acid and derivatives (three locations) acrolein occurs only as an unisolated intermediate. Refined acrolein is produced at two locations. (One plant produces both acrylic acid and refined acrolein.) The emission sources and resulting emissions are significantly different for the two types of processes.

The predominant source of acrolein emissions from plants producing acrylic acid is the off-gas from the quench-absorber.[4] Other associated emission components include propane, propylene, acrylic acid, ethyl acrylate, acetone, and acetic acid. Emissions from this source are normally controlled by thermal oxidation.[4] With acrolein occurring only as an unisolated intermediate, storage emissions are negligible.[6,7] Fugitive emissions are those which result from plant equipment leaks.

The predominant sources of acrolein emissions from plants producing refined acrolein are the acrolein absorber vent (Union Carbide Process) and the condenser vents from the distillation columns. Other associated emission components include propane, propylene, and acetaldehyde.[3] With the use of pressurized tanks for storage the emissions of acrolein from storage sources are negligible.

Vent stack data for acrolein are shown in Table 2-4. Data for plants producing refined acrolein are also given in Table 2-4. Both types of production facilities are usually "open-air" structures without walls and solid floors (i.e., steel grating). Only the control room area is enclosed.

Uses

The acrolein produced by acrylic acid manufacturers (308 million lb in 1978), which accounts for 87% of acrolein production, occurs as an unisolated intermediate. End-use emissions are included in production emissions. Similarly, the emissions of acrolein from the production of glycerin (7% of total acrolein consumption) are included in the production emissions since the glycerin is produced in the same plant.

Table 2-3. 1978 Acrolein Production Emissions

Company	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions (lb/yr)	Total Emissions (g/sec)[a]
Shell	Norco, LA	26,400	0	2,640	29,040[b]	0.418
Union Carbide	Taft, LA	24,200	0	2,420	26,620[b]	0.383
Celanese	Clear Lake, TX	5,520	0	445	5,965[c]	0.086
Rohm and Haas	Deer Park, TX	9,050	0	730	9,780[c]	0.141
Union Carbide	Taft, LA	4,530	0	365	4,895[c]	0.071
Total		69,700	0	6,600	76,300	

[a] Based on 8760 hr/yr operation.

[b] Isolated acrolein emission factor (lb lost per lb produced). See ref. 3.

Process	0.00110	A - Derived from site visit data
Storage	0	A - Derived from site visit data
Fugitive	0.00011	A - Derived from site visit data
Total	0.00121	

[c] Unisolated acrolein emission factor (lb lost per lb acrolein produced). See ref. 4.

Process	0.000062	A - Derived from site visit data
Storage	0	A - Derived from site visit data
Fugitive	0.000005	A - Derived from site visit data
Total	0.000067	

Table 2-4. Acrolein Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)
Production[a,b,c] (acrylic acid mfgs)					
Process	1	50	2.7	70	50
Production[b,c] (refined acrolein)					
Process	1	120	0.3	70	72
End-use (Methionine)[b,d]					
Process	1	40	0.6	70	5

[a] Individual process vents are collected and fed to a single thermal oxidizer.

[b] Storage emissions are negligible.

[c] Building cross-section 10 m^2.

[d] Building cross-section 100 m^2.

Emissions resulting from the use of acrolein in the production of methionine and its derivatives, and in miscellaneous uses, were estimated by using the refined (isolated) acrolein production emission factor. Specific source locations for methionine manufacturers are shown in Table 2-5. Acrolein usage was distributed evenly over all four sites since capacities were not known. Specific locations for miscellaneous uses could not be identified.

Total nationwide emissions of acrolein in 1978 from all sources are estimated to have been 102,920 lb. A tabulation of the losses is shown in Table 2-6.

Table 2-5. 1978 Emissions of Acrolein from Methionine Production[a]

Company	Location	1978 Estimate Acrolein Used (M̄ lbs)	Process Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[b,c] (lb/yr)	Total Emissions[b,c] (g/sec)[d]	Geographic Coordinates Latitude/Longitude
Degussa	Theodore, AL	5.0	5,500	550	6,050	0.087	30 33 06/88 10 35
NAPP	Lodi, NJ	5.0	5,500	550	6,050	0.087	40 52 30/74 06 14
Dupont	Beaumont, TX	5.0	5,500	550	6,050	0.087	30 00 51/94 01 40
Monsanto	Nitro, WV	5.0	5,500	550	6,050	0.087	38 24 26/81 51 26
Total		20.0	22,000	2,200[e]	24,200		

---

[a] See ref. 1.

[b] Based on isolated acrolein production emission factor.

[c] Storage emissions negilible.

[d] Based on 8760 hr/yr operation.

[e] Fugitive losses are distributed over a 100 ft X 100 ft area.

Table 2-6. 1978 Estimated Acrolein Nationwide Emission Losses

Source	Estimated National Emissions (lb/yr)
Production	
Acrylic acid intermediate	20,640
Refined acrolein and glycerin	55,660
Chemical intermediate*	
Methionine	24,200
Miscellaneous	2,420
Total	102,920

*Based on emission factor of 0.00121 determined for isolated acrolein production.

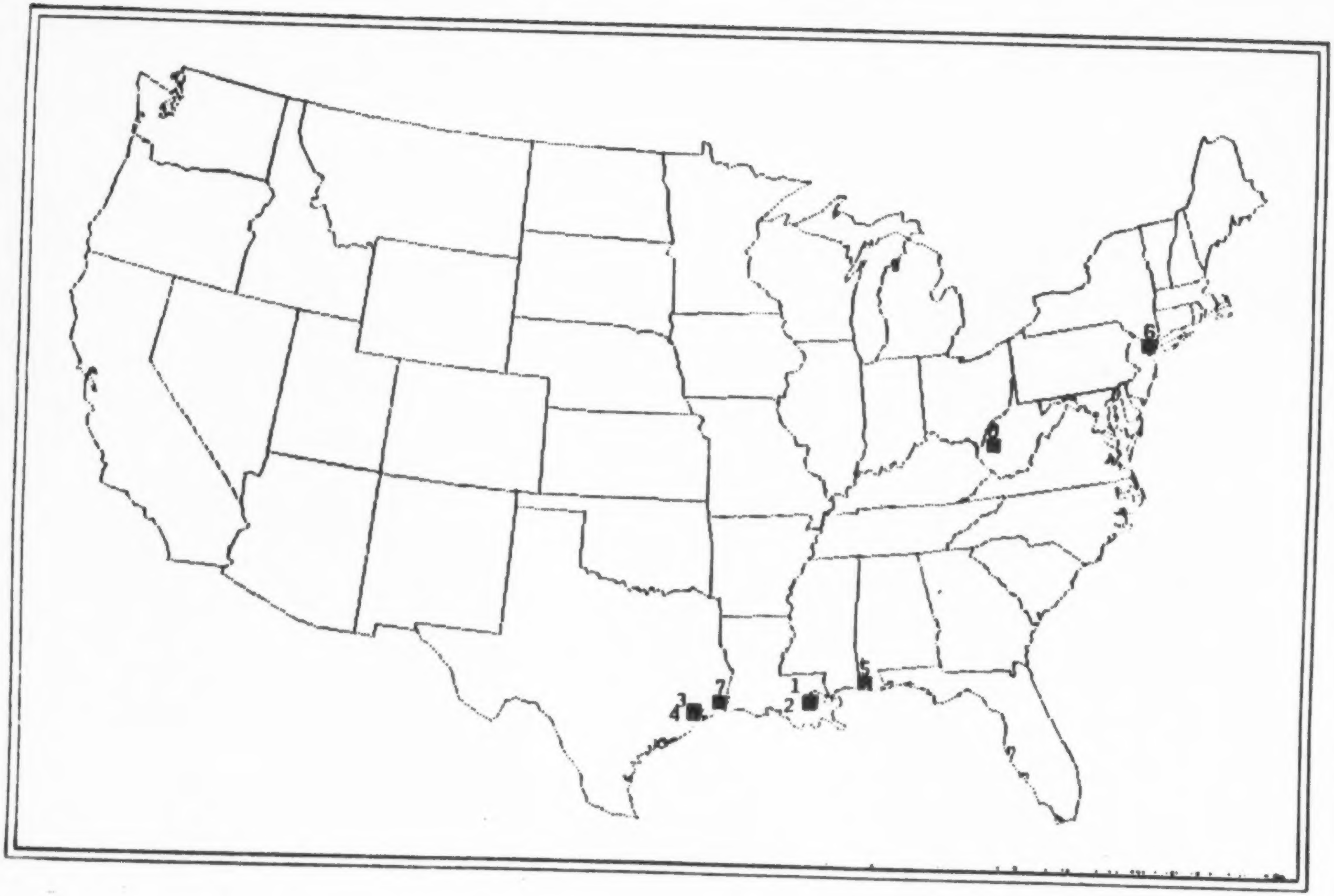


FIGURE 2-1. SPECIFIC POINT SOURCES OF ACROLEIN EMISSIONS

TABLE 2-7. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF ACROLEIN

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	SHELL	NORCO, LA	30 00 11	090 23 42	12958	1	1	.380160	0.	.038016
2	UNION CARBIDE	TAFT, LA	29 58 00	090 27 00	13970	2	1 2	.348400 .065232	0. 0.	.034848 .005256
3	CELANESE	CLEAR LAKE, TX	29 37 17	095 03 51	12906	3	2	.079408	0.	.006408
4	ROHMAND HAAS	DEER PARK, TX	29 43 30	095 06 30	12906	3	2	.130320	0.	.010512
5	DEGUSSA	THEODOR, AL	30 33 06	088 10 35	03855	4	3	.079200	0.	.007920
6	NAPP	LODI, NJ	40 52 30	074 06 14	94741	4	3	.050400	0.	.007920
7	DUPONT	BEAUMONT, TX	30 00 51	094 01 40	12917	4	3	.079200	0.	.007920
8	MONSANTO	NITRO, WV	38 24 26	081 51 26	13866	4	3	.079200	0.	.007920

---

* Plant Types:

Type 1: Plant produces refined acrolein

Type 2: Plant produces refined acrolein and acrylic acid

Type 3: Plant produces acrylic acid and acrolein is the intermediate

Type 4: Plant produces methionine

† Source Types:

Type 1: Refined acrolein production

Type 2: Acrylic acid production

Type 3: Methionine production

TABLE 2-8. EXPOSURE AND DOSAGE OF ACROLEIN RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m³)	Population Exposed (persons)	Dosage [(ug/m³) · persons]
1	129	141
0.5	671	491
0.25	1,985	955
0.1	8,034	1,730
0.05	13,169	2,080
0.025	25,183	2,530
0.01	58,727	3,060
0.005	121,420	3,490
0.0025	287,635	4,060
0.001	813,153	4,860
0.0005	1,256,386	5,190
6.3×10^{-13}*	6,692,103	5,290

---

*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 2-9. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF ACROLEIN

Parameter	Value
Daytime decay rate (K_d)	1.6×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	5.0×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	0.0348 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 2-10. **ACROLEIN EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS**

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.000100	505140	91.0	0.	100.0	0.	100.0	0.	0.
.000050	9149730	589.8	0.	100.0	0.	100.0	0.	0.
.000025	20443737	925.3	0.	100.0	0.	100.0	0.	0.
.000010	55204345	1443.0	0.	100.0	0.	97.4	.9	1.7
.000005	127350709	1987.4	0.	100.0	0.	94.2	2.6	3.2
0.	158679135	2093.0	0.	100.0	0.	91.8	3.0	5.3

TABLE 2-11. EXPOSURE AND DOSAGE SUMMARY OF ACROLEIN

Concentration Level (μg/m³)	Population Exposed (persons)				Dosage [(μg/m³)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
1	129	0	0	129	141	0	0	141
0.5	671	0	0	671	491	0	0	491
0.25	1,985	0	0	1,985	955	0	0	955
0.1	8,034	0	0	8,034	1,730	0	0	1,730
0.05	13,169	0	0	13,169	2,080	0	0	2,080
0.025	25,183	0	0	25,183	2,530	0	0	2,530
0.01	58,727	0	0	58,727	3,060	0	0	3,060
0.005	121,420	0	0	121,420	3,490	0	0	3,490
0.0025	287,635	0	0	287,635	4,060	0	0	4,060
0.001	813,153	0	0	813,153	4,860	0	0	4,860
0.0005	1,256,386	0	0	1,256,386	5,190	0	0	5,190
0.0001	--	0	505,140	--	--	0	91	--
0.00005	--	0	9,149,730	--	--	0	590	--
0.000025	--	0	20,443,737	--	--	0	925	--
0.00001	--	0	55,204,345	--	--	0	1,443	--
0.000005	--	0	127,350,709	--	--	0	1,987	--
0	6,692,103	0	158,679,135	--	5,290	0	2,094	7,384

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. S. L. Soder and K. Ring, "Propylene," pp. 300.5405E—300.5405L in *Chemical Economics Handbook*, Stanford Research Institute, Menlo Park, CA (August 1978).

2. J. L. Blackford, "Epichlorohydrin," pp. 642.3021A—642.3022M in *Chemical Economics Handbook*, Stanford Research Institute, Menlo Park, CA (May 1978).

3. C. A. Peterson, Jr., Hydroscience, Inc., *Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Glycerin and Its Intermediates (Allyl Chloride, Epichlorohydrin, Acrolein, and Allyl Alcohol* (on file at EPA, ESED, Research Triangle Park, NC)(March 1979).

4. J. W. Blackburn, Hydroscience, Inc., *Emisson Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Acrylic Acid and Esters Product Report* (on file at EPA, ESED, Research Triangle Park, NC) (July 1978).

5. CEH Manual of Current Indicators——Supplementary Data, p. 84 in *Chemical Economics Handbook*, Stanford Research Institute, Menlo Park, CA (April 1979).

6. D. B. Dimick, Dow Chemical, Freeport, TX, Texas Air Control Board Emissions Inventory Questionnaire for 1975, Epichlorohydrin, Glycerin No. 1.

7. Dow Chemical Co., Freeport, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Allyl Chloride, Glycerin II.

8. Shell Chemical Co., Deer Park, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Glycerin and Associated Products.

9. Shell Chemical Co., Norco, LA, Louisiana Air Control Commission Emission Inventory Questionnaire (January 31, 1977).

10. Shell Chemical Co., Deer Park, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Resins Process.

APPENDIX A-3 ----- Allyl Chloride

ALLYL CHLORIDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 107-05-1

Synonyms: 3-Chloroprene; AC; Chlorallylene; 3-Chloro-1-propene;
1-Chloro-2-propene; 3-Chloropropylene

Chemical Formula

Molecular Weight: 76.53

Molecular Formula: C_3H_5Cl

Molecular Structure: $CH_2 = CH - CH_2Cl$

Chemical and Physical Properties

Physical State at STP: Liquid, pungent odor

Boiling Point: 44.6°C

Melting Point: -134.5°C

Density: 0.938 at 20°C/4°C

Vapor Pressure: 359 mm at 25°C

Vapor Density: 2.64

Solubility: Soluble (33 g/l of H_2O) at 20°

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products: 2-Chloroacetaldehyde; Formaldehyde

Reactivity Toward OH·: 2 x Butane

Reactivity Toward O_3: 15% of propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

A. ALLYL CHLORIDE

All allyl chloride currently produced in the United States by the chlorination of propylene is consumed in the production of epichlorohydrin.[1,2] Allyl chloride is first reacted with hypochlorous acid to form dichlorohydrin; dichlorohydrin is then reacted with sodium hydroxide or calcium hydroxide to form crude epichlorohydrin.[2]

Crude epichlorohydrin can be used directly for the production of synthetic glycerin.[2] For other end-uses (primarily expoxy resins) the crude product is further refined by distillation.[2]

Allyl chloride and epichlorohydrin are both produced by two companies at three locations.[2] The plant locations and the 1978 capacities and estimated production levels for each plant are shown in Table 3-1.[1,2] The estimated quantities of allyl chloride and epichlorohydrin produced in 1978 were 330 million lb and 312 million lb respectively.[2]

The primary end-uses of epichlorohydrin are for the manufacture of epoxy resins and synthetic glycerin. An estimated 53% of epichlorohydrin production amounting to 165 million lb was consumed to produce epoxy resins and 25%, or 78 million lb, was consumed in the manufacture of synthetic glycerin.[1,2]

Most of the other applications of epichlorohydrin are relatively minor. Epichlorohydrin elastomers consumed an estimated 6 million lb (2%) in 1978. An estimated 47 million lb (15%) was used to produce a variety of products in relatively small volume including glycidol ethers, some types of modified epoxy resins, wet strength resins for the paper industry, water treatment resins, surfactants, and ion-exchange resins. Exports of epichlorohydrin are estimated to have been 16 million lb (5%) in 1978. End-uses are summarized in Table 15-2.[1,2] Specific source locations of the epoxy resin producers are shown in Table 15-3.[1,2]

EMISSIONS ESTIMATES

1. Production

Estimated production losses are shown in Table 3-2 for each of the three producing locations. Total emissions of allyl chloride and epichlorohydrin from production facilities are estimated to have been 1,112,100 lb and 146,640 lb respectively in 1978.[3] Process emissions originate primarily through the condenser vents

Table 3-1. Production of Allyl Chloride, Epichlorohydrin, and Acrolein[a]

Source	Location	1978 Estimated Production[b] (M lb)			1978 Estimated Capacity (M lb)			Geographic Coordinates
		Allyl Chloride	Epichlorohydrin	Acrolein	Allyl Chloride	Eqichlorohydrin	Acrolein	Latitude/Longitude
Dow Chemical Co.	Freeport, TX	176	166		265	250		28 59 30/95 23 35
Shell Chemical Co.	Deer Park, TX	77	73		117	110		29 42 55/95 07 34
Shell Chemical Co.	Norco, LA	77	73	24[c]	117	110	55[c]	30 00 11/90 23 42
Union Carbide Corp.	Taft, La			22[c]			60[c]	29 58 00/90 27 00
Celanese Corp.	Clear Lake, TX			89[d]			167[d]	29 37 17/95 03 51
Rohm and Haas Co.	Deer Park, TX			146[d]			273[d]	29 43 30/95 06 15
Union Carbide Corp.	Taft, LA			73[d]			137[d]	29 58 00/90 27 00
Total		330	312	354	499	470	692	

[a] See refs 1 and 2.

[b] The distribution of production for each producer is determined by the ratio of total U.S. production to total U.S. capacity as compared to individual plant capacity.

[c] Isolated acrolein.

[d] Acrolein produced as an unisolated intermediate in the propylene oxidation process for acrylic acid and derivitives.

Table 3-2. 1978 Allyl Chloride and Epichlorohydrin Production Emissions

		Process Emissions		Storage Emissions		Fugitive Emissions		Total Emissions			
								Allyl Chloride[a]		Epichlorohydrin[b]	
Company	Location	Allyl Chloride (lb/yr)	Epichlorohydrin (lb/yr)	Allyl Chloride (lb/yr)	Epichlorohydrin (lb/yr)	Allyl Chloride (lb/yr)	Epichlorohydrin (lb/yr)	(lb/yr)	(g/sec)[c]	(lb/yr)	(g/sec)[c]
Dow	Freeport, TX	515,680	69,720	24,640	1,660	52,800	6,640	593,120	8.54	78,020	1.12
Shell	Deer Park, TX	225,610	30,660	10,780	730	23,100	2,920	259,490	3.74	34,310	0.49
	Norco, LA	225,610	30,660	10,780	730	23,100	2,920	259,490	3.74	34,310	0.49
Total		966,900	131,040	46,200	3,120	99,000	12,480	1,112,100		146,640	

[a] Based on allyl chloride emission factor (lb lost/lb produced). See refs. 7—9.

Process	0.00293	B - From state files
Storage	0.00014	B - From state files
Fugitive	0.00030	D - Engineering estimate
Total	0.00337	

[b] Based on epichlorohydrin emission factor (lb lost/lb produced). See refs. 6, 8, and 9.

Process	0.00042	B - Fron state files
Storage	0.00001	B - From state files
Fugitive	0.00004	D - Engineering estimate
Total	0.00047	

[c] Based on 8760 hr/yr operation.

from the distillation columns.[3] Other associated emissions include C_3 hydrocarbons and other C_3 chlorinated hydrocarbons.[3] Storage emissions, which represent total losses from storage tanks and loading and handling, are generally controlled by the use of pressurized tanks and/or refrigerated vent condensers and account for less than 5% of allyl chloride losses and less than 3% of epichlorohydrin losses.[6,7] Fugitive emissions are those which result from plant equipment leaks.

Vent stack data are shown in Table 3-3. Typically, there are four process vents that emit allyl chloride and three process vents that emit epichlorohydrin. Emissions from banks of storage tanks are normally collected and discharged from common vent stacks. Usually allyl chloride/epichlorohydrin production facilities are "open-air" structures without walls and solid floors (i.e., steel grating). Only the control room area is enclosed.

2. Uses

For the purpose of this report, emissions resulting from the export of epichlorohydrin are assumed to be negligible.

Since the only significant end-use for allyl chloride is in the production of epichlorohydrin, allyl chloride end-use emissions are included in the allyl chloride/epichlorohydrin production emissions.

More than half (53%) of the epichlorohydrin produced is used in the production of epoxy resins. The current domestic producers of epoxy resins, plant locations, and estimated emissions of epichlorohydrin are given in Table 15-6. Vent parameter data relative to epichlorohydrin emissions from epoxy resin production are shown in Table 3-3.

Emissions of epichlorohydrin resulting from the production of glycerin, the next largest end-use of epichlorohydrin (25%), are included in the listed epichlorohydrin production emissions. (Glycerin and the required epichlorohydrin are produced at the same location.) Emissions resulting from the use of epichlorohydrin in the production of miscellaneous products were estimated by using the epoxy resin (epichlorohydrin use) emission factor. Specific source locations for miscellaneous chemical intermediate use could not be identified.

Total nationwide emissions of allyl chloride and epichlorohydrin in 1978 from all sources are estimated to have been 1.11 million lb and 0.479 million lb respectively. A tabulation of the losses is shown in Table 3-4.

Table 3-3. **Allyl Chloride and Epichlorohydrin Vent Parameters**

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
Production[a,b]					
Process vents					
Allyl chloride	2	85	0.6	80	Intermittent
	2	40	0.167	228	5.5
Epichlorohydrin	3	50	0.34	90	13.8
Storage vents					
Allyl chloride	2	15 - 20	0.6	86	
Epichlorohydrin	2	15 - 20	0.6	80	
Use[c,d]					
Epoxy resins, elastomers and misc. products					
Process					
Column vent	1	50	0.33	115	5.3
Recovery vents	3	135	0.83	110	10.0
Storage	7	20	0.17	80	

[a] Building cross-section 5 m^2.

[b] Fugitive emissions distributed over a 300 ft X 300 ft area.

[c] Building cross-section 100 m^2.

[d] Fugitive emissions distributed over a 100 ft X 200 ft area.

Table 3-4. **1978 Estimated Allyl Chloride and Epichlorohydrin Nationwide Emission Losses**

	Estimated National Emissions	
Source	**Allyl Chloride (M lb/yr)**	**Epichlorohydrin (M lb/yr)**
Production (allyl chloride, epichlorohydrin, and glycerin)	**1.11**	**0.147**
Unmodified epoxy resins - use		**0.251**
Chemical intermediate - use		**0.081**
Export	**0**	**0**
Total	**1.11**	**0.479**

***Based on emission factor of 0.00152 lb lost per lb used derived for epoxy resin manufacture.**

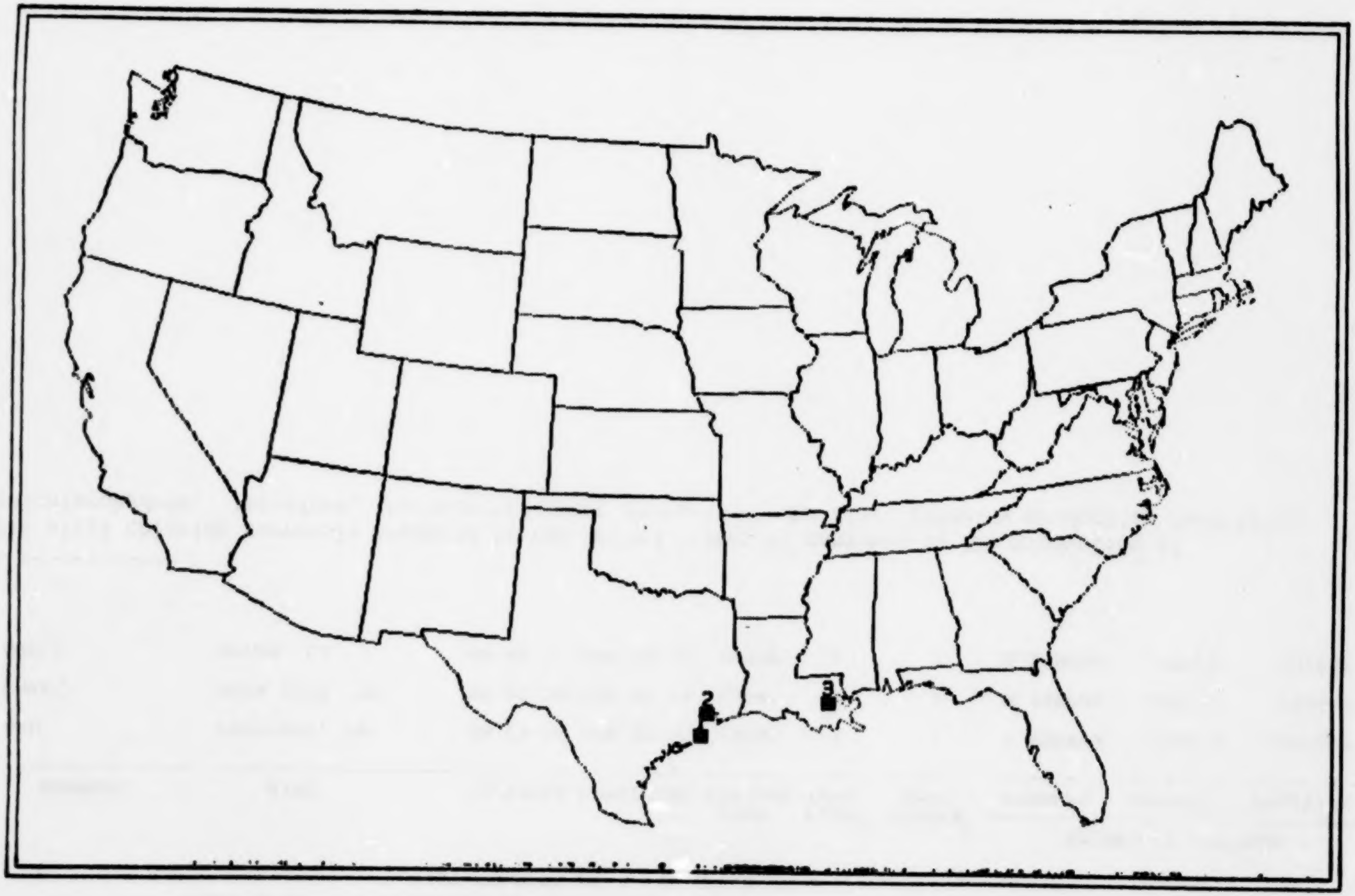


FIGURE 3-1. SPECIFIC POINT SOURCES OF ALLYL CHLORIDE EMISSIONS

TABLE 3-5. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF ALLYL CHLORIDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE* TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	1	1	7.425792	.354816	.760320
2	SHELL	DEER PARK, TX	29 42 55	095 07 34	12906	1	1	3.248784	.155232	.332640
3	SHELL	NORCO, LA	30 00 11	090 23 42	12958	1	1	3.248784	.155232	.332640

---

* All allyl chloride currently produced in the United States is consumed in the production of epichlorohydrin. Therefore, the only emissions sources are the allyl chloride production facilities.

TABLE 3-6. EXPOSURE AND DOSAGE OF ALLYL CHLORIDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
25	9	285
10	59	1,060
5	137	1,620
2.5	298	2,220
1	937	3,160
0.5	3,009	4,540
0.25	4,744	5,130
0.1	17,436	6,800
0.05	33,654	7,860
0.025	62,662	9,020
0.01	75,858	9,240
1.61×10^{-8}*	940,365	9,770

---

*The lowest annual average concentration occurring within 20 km of the specific point source.

REFERENCES

1. S. L. Soder and K. Ring, "Propylene," pp. 300.5405E—300.5405L in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (August 1978).

2. J. L. Blackford, "Epichlorohydrin," pp. 642.3021A—642.3022M in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (May 1978).

3. C. A. Peterson, Jr., Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Glycerin and Its Intermediates (Allyl Chloride, Epichlorohydrin, Acrolein, and Allyl Alcohol (on file at EPA, ESED, Research Triangle Park, NC)(March 1979).

4. J. W. Blackburn, Hydroscience, Inc., Emisson Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Acrylic Acid and Esters Product Report (on file at EPA, ESED, Research Triangle Park, NC) (July 1978).

5. CEH Manual of Current Indicators——Supplementary Data, p. 84 in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (April 1979).

6. D. B. Dimick, Dow Chemical, Freeport, TX, Texas Air Control Board Emissions Inventory Questionnaire for 1975, Epichlorohydrin, Glycerin No. 1.

7. Dow Chemical Co., Freeport, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Allyl Chloride, Glycerin II.

8. Shell Chemical Co., Deer Park, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Glycerin and Associated Products.

9. Shell Chemical Co., Norco, LA, Louisiana Air Control Commission Emission Inventory Questionnaire (January 31, 1977).

10. Shell Chemical Co., Deer Park, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Resins Process.

APPENDIX A-4 ----- Benzyl Chloride

BENZYL CHLORIDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 100-44-7

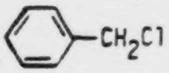
Synonyms: α-Tolylchloride; Chloromethylbenzene; α-Chlorotoluene

Chemical Formula

Molecular Weight: 126.5

Molecular Formula: C_7H_7Cl

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - very refractive, irritating odor

Boiling Point: 179°C at 760 mm

Melting Point: -39°C

Density: 1.1026 at 18°C/4°C

Vapor Pressure: 1.4 mm at 25°C

Vapor Density: 4.36

Solubility: Insoluble (H_2O)

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 2 x Butane

Reactivity Toward O_3: No reaction

Reactivity Toward Photolysis: No photochemical degradation

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

Benzyl chloride ($C_6H_5CH_2Cl$) is currently produced in the United States by the direct chlorination of boiling toluene. In this process, boiling toluene is chlorinated in the absence of light until the proper weight increase is achieved. The reaction mixture is then agitated with mild alkali and distilled. Benzyl chloride and benzotrichloride are formed as by-products. Other processes for producing benzyl chloride which are not in use in the U.S. today include chlorination of toluene using sulfuryl chloride and the chloromethylation of benzene using formaldehyde and hydrogen chloride.

There are currently three producers of benzyl chloride at four locations in the United States. The site locations of the plants and the 1978 capacity and estimated production levels for each plant are shown in Table 4-1.[1] In 1978 an estimated 115 million lb of benzyl chloride was produced.

B. USES

The major use of benzyl chloride is for the production of butyl benzyl phthalate, a plasticizer used in the manufacture of polyvinyl chloride (PVC) for floor coverings. An estimated 75% (86.25 million lb) of benzyl chloride production was consumed for this end-use. Butyl benzyl phthalate is produced by reacting butyl alcohol, benzyl chloride, and phthalic anhydride in the presence of an acid catalyst. The site locations of the butyl benzyl phthalate producers are shown in Table 4-2.[2]

Quaternary ammonium compounds are the second largest outlet for benzyl chloride. They are formed by reacting benzyl chloride with dimethyl alkyl amines and are used primarily as germicides. Approximately 10% (11.5 million lb) was consumed for this end-use. Source locations of the major quaternary ammonium compound manufactures are shown in Table 4-3.[2]

Benzyl alcohol production consumed 7% of benzyl chloride production (8.0 million lb). Benzyl alcohol is made by the hydrolysis of benzyl chloride with an alkali. Benzyl alcohol is used primarily as a textile dye assistant. Source locations of benzyl alcohol producers are shown in Table 4-4.[3]

Table 4-1. Benzyl Chloride Producers[a]

Company	Location	1978 Capacity (10^6 lb/yr)	1978[b] Production (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Monsanto	Bridgeport, NJ	80	52.5	39 47 33/75 23 45
	Sauget, IL	80	52.5	38 35 31/90 10 11
Stauffer	Edison, NJ	12	8.0	40 29 23/74 23 03
UOP, Inc.	East Rutherford, NJ	3	2.0	40 49 46/74 05 30
Total		175	115.0	

---

[a] See ref. 1.

[b] Based on ratio of production to capacity of 66% (see ref. 1).

Table 4-2. Butyl Benzyl Phthalate Producers[a]

Company	Location	1978 Butyl Benzyl Phathalate Capacity (10^6 lb/yr)	1976 Benzyl Chloride[b] Used (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Monsanto	Bridgeport, NJ	NA[c]	43.125	39 47 33/75 23 45
	Sauget, IL	NA	43.125	38 35 31/90 10 11
Total			86.25	

[a] See ref. 2.

[b] Total benzyl chloride use of 86.25 million lb was distributed evenly over both sites since capacity data were not available.

[c] Not available.

Table 4-3. Quaternary Ammonium Compounds Producers[a]

Company	Location	Quaternary Ammonium Compound Capacity (lb/yr)	Benzyl Chloride[b] Used (lb/yr)	Geographic Coordinates Latitude/Longitude
Akzona	McCook, IL	NA[c]	92,500	41 48 17/87 49 41
	Morris, IL	NA	92,500	41 24 24/88 18 10
Lonza	Mapleton, IL	NA	92,500	40 34 00/89 43 01
Hexcel	Lodi, NJ	NA	92,500	40 52 00/74 06 50
Witco	Houston, TX	NA	92,500	29 34 45/95 26 00
Ashland	Janesville, WI	NA	92,500	42 41 56/89 00 10
Gulf Oil	Jersey City, NJ	NA	92,500	40 43 02/74 06 14
Rohm & Haas	Philadelphia, PA	NA	92,500	39 54 50/75 11 30
Sterling	Cincinnati, OH	NA	92,500	39 05 15/84 33 09
National Starch	Salisbury, NC	NA	92,500	35 43 36/80 28 19
Total			9,250,000	

[a] See ref. 2.

[b] Total benzyl chloride usage distributed evenly over all 10 sites.

[c] Not available.

Table 4-4. Benzyl Alcohol Producers[a]

Company	Location	1978 Capacity Benzyl Alcohol (10^6 lb/yr)	1978[b] Benzyl Chloride Use (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Stauffer Chemical	Edison, NJ	5	2.7	40 29 23/74 23 07
UOP, Inc.	E. Rutherford, NJ	2	1.0	40 49 46/74 05 30
Velsicol	Chattanooga, TN	5	2.7	30 36 31/85 16 36
Orbis	Newark, NJ	1.5	0.8	40 41 16/74 12 17
Norda	Boonton, NJ	1.5	0.8	40 54 13/74 24 44
Total		15	8.0	

[a] See ref. 3.

[b] Based on 7% of benzyl chloride that is used to make benzyl alcohol (sse ref. 1).

Benzyl alcohol used = $\frac{\text{BA capacity}}{15} \times 0.07$ (115×10^6 lb/yr benzyl chloride produced).

The remaining benzyl chloride production (8%) representing 9.25 million lb was used in a variety of small diverse chemical intermediate end-uses. Benzyl chloride end-uses are summarized in Table 4-5.[1]

II. EMISSION ESTIMATES

A. PRODUCTION

Benzyl chloride emissions from production sites are presented in Table 4-6. Total estimated emissions from these sites for 1978 were 58,860 lb. Emission factors derived from state files[4,5] included both benzyl chloride production emissions and benzyl alcohol consumption emissions. They apply only to Stauffer at Edison, NJ and UOP at E. Rutherford, NJ. Emission factors used to develop process, storage, and fugitive emissions from Monsanto's two facilities were taken from published data.[6] Both factors are shown in Table 4-7. Process emissions originate primarily from scrubber vents and vacuum jets. Other associated emission components would include toluene, hydrochloric acid, and chlorine.

Storage emissions represent the losses from both working and final product storage as well as loading and handling losses. Fugitive emissions are those that are result from plant equipment leaks.

Vent parameter data are reported in Table 4-8 for both producers and end-users.

B. USES

Emission estimates for end-users of benzyl chloride are summarized along with production emissions in Table 4-6. They are based on the emission factors tabulated in Table 4-7.

Benzyl chloride emissions from butyl benzene phthalate production are estimated to have been 27,168 lb. Other associated emissions would include phthalic anhydride and butanol.

Benzyl chloride emissions from benzyl alcohol production are estimated to have been 2150 lb. However the emissions from benzyl alcohol manufactured at Stuaffer and UOP are already included in the benzyl chloride production emission losses.

Table 4-5. Benzyl Chloride End-Uses 1978*

Use	Usage (10^6 lb/yr)	Usage (%)
Butyl benzyl phthalate	86.25	75
Benzyl alcohol	8.0	7
Quaternary ammonium compounds	11.5	10
Miscellaneous	9.25	8
Total	115	100

*See ref. 1.

Table 4-6. Benzyl Chloride Emissions from Producers and Users

Company	Location	Source	Emissions (lb/yr) Process	Storage	Fugitive	Total Emissions[a] (lb/yr)	(g/sec)[b]
Monsanto	Bridgeport, NJ	Production	20,633	1785	3833	26,250	0.378
	Sauget, IL	Production	20,633	1785	3833	26,250	0.378
Stauffer	Edison, NJ	Production	4,000	344	744	5,088	0.073
UOP	E. Rutherford, NJ	Production	1,000	86	186	1,272	0.018
Monsanto	Bridgeport, NJ	BBP	10,178	1078	2329	13,584	0.196
	Sauget, IL	BBP	10,178	1078	2329	13,584	0.196
Velsicol	Chattanooga, TN	Benzyl alcohol	945	108	297	1,350	0.019
Orbis	Newark, NJ	Benzyl alcohol	280	32	88	400	0.006
Norda	Boonton, NJ	Benzyl alcohol	280	32	88	400	0.006
Akzona	McCook, IL	QAC	322	46	92	460	0.007
	Morris, IL	QAC	322	46	92	460	0.007
Lonza	Mapelton, IL	QAC	322	46	92	460	0.007
Hexcel	Lodi, NJ	QAC	322	46	92	460	0.007
Witco	Houston, TX	QAC	322	46	92	460	0.007
Ashland	Janesville, WI	QAC	322	46	92	460	0.007
Gulf Oil	Jersey City, NJ	QAC	322	46	92	460	0.007
Rohm & Haas	Philadelphia, PA	QAC	322	46	92	460	0.007
Sterling	Cincinnati, OH	QAC	322	46	92	460	0.007
National Starch	Salisbury, NC	QAC	322	46	92	460	0.007
Total			71,347	6788	14,647	92,778	

[a] Based on emission factors shown in Table 7.

[b] Based on 8760 hr/yr operation.

Table 4-7. Benzyl Chloride Emission Factors

Source	Emission Factor (lb lost/lb produced)(used)						
	Process	Derivation[a]	Storage	Derivation	Fugitive	Derivation	Total
Benzyl chloride production (Monsanto sites)	0.000393	C	0.000034	C	0.000073	C	0.000500[c]
Benzyl chloride production[b] (Stauffer/UOP)	0.000500	B	0.000043	B	0.000093	B	0.000636[d]
Butyl benzyl phthalate	0.000236	C	0.000025	C	0.000054	C	0.000315[c]
Benzyl alcohol	0.000350	C	0.000040	C	0.000110	C	0.000500[c]
Quaternary ammonium compounds	0.000280	D	0.000040	D	0.000080	D	0.000400[e]

[a] A - basis site visit data
B - basis state emission files
C - basis published data
D - basis Hydroscience estimate

[b] Emission factor represents benzyl chloride production and benzyl alcohol use loss.

[c] See ref. 6.

[d] See refs. 4 and 5.

[e] Hydroscience estimate.

Table 4-8. Benzyl Chloride Vent Paremeters

	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temp. (°F)	Velocity (ft/sec)	Distribution Area
Production						
Process	2	38	1.0	78	0.02	
Storage	6	24	0.17	70	0.02	
Fugitive						300 X 300
Butyl benzyl phthalate						
Process	1	36	0.6	90	5	
Storage	4	24	0.33	80		
Fugitive						200 X 300
Quaternary NH_3 compounds						
Process	1	20	0.33	75	14	
Storage	1	8	0.17	70		
Fugitive						100 X 100
Benzyl alcohol						
Process	2	36	0.33	80	10	
Storage	2	20	0.17	70		
Fugitive						300 X 300

Building cross-section for all sources - 50 m^2.

Quaternary ammonium compounds manufacture contributed an estimated 4600 lb of benzyl chloride emissions. Other emission components would likely be amines. Miscellaneous uses of benzyl chloride were estimated to have contributed 7493 lb of emissions. These uses are extremely small and too diverse and numerous to locate and specify individual emission quantities. Emissions were estimated by taking a weighted average of the other benzyl chloride end-uses and multiplying by the 9.25 million lb used.

The total nationwide emissions of benzyl chloride in 1978 were estimated to have been 100,271 lb. A tabulation of the losses is shown in Table 4-9.

Table 4-9. Benzyl Chloride Nationwide Emissions

Source	Nationwide Emissions (lb/yr)
Production	58,860[a]
Butyl benzyl phthalate	27,168
Quaternary ammonium compounds	4,600
Benzyl alcohol	2,150[a]
Miscellaneous[b]	7,493
Total	100,271

[a] Emissions from the use of 3.7 million lb of benzyl chloride to produce benzyl alcohol are included in production.

[b] Based on a weighted average emission factor for all benzyl chloride uses of 0.000405 lb lost/lb used.

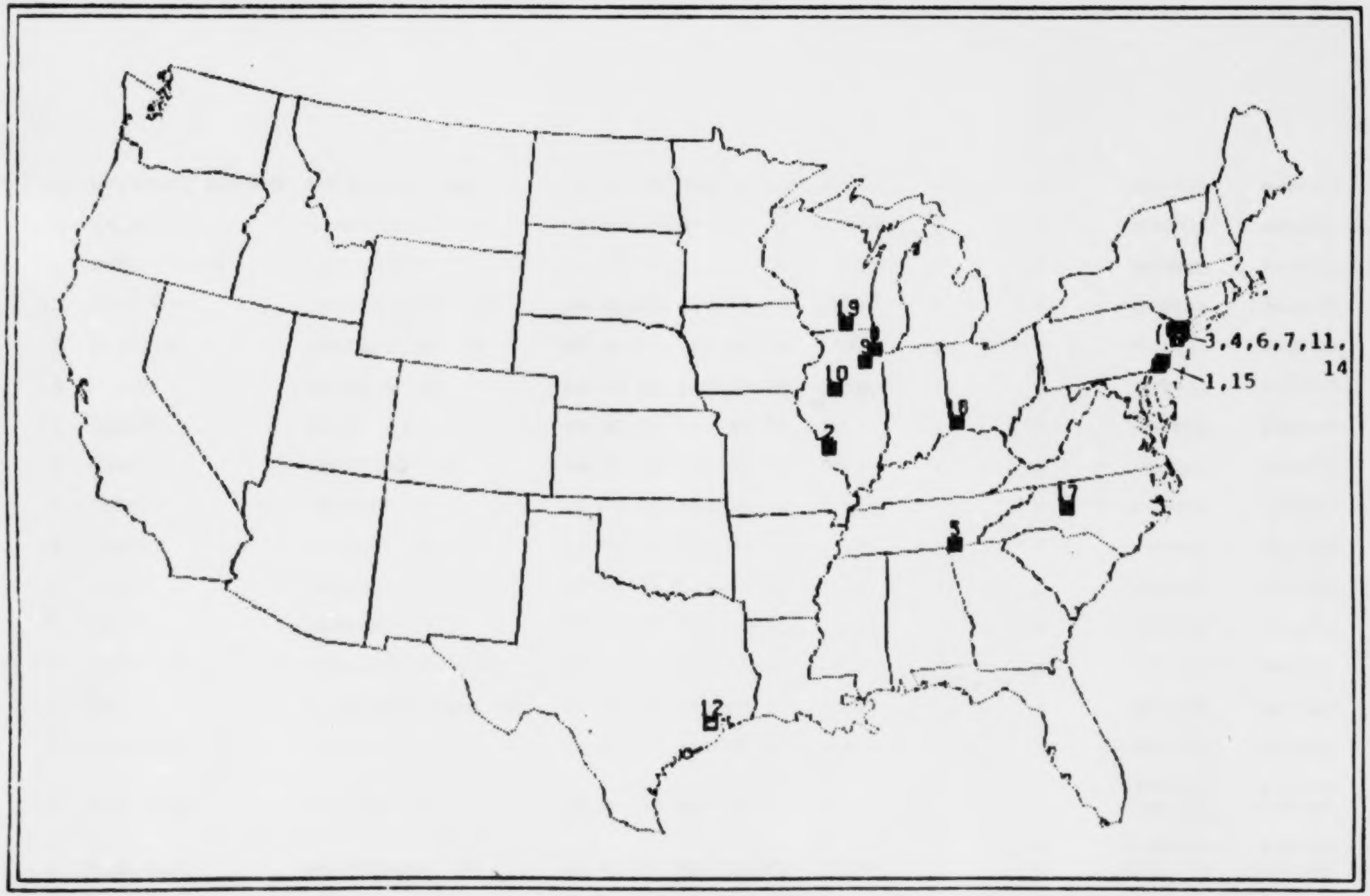

19
8
9
10
2
16
17
5
12
3,4,6,7,11,
14
1,15

FIGURE 4-1. SPECIFIC POINT SOURCES OF BENZYL CHLORIDE EMISSIONS

TABLE 4-10. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF BENZYL CHLORIDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	MONSANTO	BRIDGEPORT, NJ	39 47 33	075 23 45	13739	1	1 2	.297115 .146563	.025704 .015523	.055195 .033538
2	MONSANTO	SAUGET, IL	38 35 31	090 10 11	13994	1	1 2	.297115 .146563	.025704 .015523	.055195 .033538
3	STAUFFER	EDISON, NJ	40 29 23	074 23 03	94741	2	1	.057660	.004954	.010714
4	UOP	E. RUTHERFORD, NJ	40 49 36	074 05 30	94741	2	1	.014400	.001238	.002678
5	VELSICOL	CHATTANOOGA, TN	35 02 31	085 16 36	13882	3	3	.013608	.001555	.004277
6	ORBIS	NEWARK, NJ	40 41 16	074 12 17	94741	3	3	.004032	.000461	.001267
7	NORDA	BOOTEN, NJ	40 54 13	074 24 44	94741	3	3	.004032	.000461	.001267
8	AKZONA	MCCOOK, IL	41 48 17	087 49 41	94846	4	4	.004637	.000662	.001325
9	AKZONA	MORRIS, IL	41 24 24	088 18 10	14855	4	4	.004637	.000662	.001325
10	LONZA	MAPELTON, IL	40 34 00	089 43 01	14842	4	4	.005357	.000662	.001325
11	HEXCEL	LODI, NJ	40 52 00	074 06 50	94741	4	4	.004637	.000662	.001325
12	WITCO	HOUSTON, TX	29 34 45	095 26 00	12906	4	4	.004637	.000662	.001325
13	ASHLAND	JANESVILLE, WI	42 41 56	089 00 10	14839	4	4	.004637	.000662	.001325
14	GULF OIL	JERSEY CITY, NJ	40 43 02	074 06 14	94741	4	4	.004637	.000662	.001325
15	ROHM & HAAS	PHILADELPHIA, PA	39 54 50	075 11 36	13739	4	4	.004637	.000662	.001325
16	STERLING	CINCINNATI, OH	39 05 15	084 33 09	13840	4	4	.004637	.000662	.001325
17	NATIONAL STARCH	SALISBURY, NC	35 43 34	080 28 19	13723	4	4	.004637	.000662	.001325

TABLE 4-10. (Concluded)

---

* Plant Types:

Type 1: Plant produces benzyl chloride and butylenzyl phthalate
Type 2: Plant produces benzyl chloride
Type 3: Plant procudes benzyl alcohol
Type 4: Plant produces quaternary ammonium compounds

† Source Types:

Type 1: Benzyl chloride production
Type 2: Butylbenzyl phthalate production
Type 3: Benzyl alcohol production
Type 4: Quaternary ammonium compounds production

TABLE 4-11. EXPOSURE AND DOSAGE OF BENZYL CHLORIDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
18.5	1	13.2
10	7	101
5	26	227
2.5	44	286
1	209	521
0.5	858	963
0.25	3,312	1,810
0.1	10,606	2,990
0.05	19,356	3,620
0.025	39,471	4,340
0.01	102,126	5,320
0.005	216,455	6,110
0.0025	449,991	6,900
0.001	1,229,667	8,110
0.0005	2,265,842	8,840
0.00025	4,270,619	9,530
0.0001	11,982,073	10,704
3.74×10^{-11}*	33,270,545	11,600

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 4-12. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF BENZYL CHLORIDE

Parameter	Value
Daytime decay rate (K_d)	2.8×10^{-5} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	0.108 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 4-13. BENZYL CHLORIDE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.000500	446952	261.9	0.	100.0	0.	100.0	0.	0.
.000250	505140	289.4	0.	100.0	0.	100.0	0.	0.
.000100	17551646	3078.7	0.	100.0	0.	100.0	0.	0.
.000050	38996868	4551.8	0.	100.0	0.	99.2	.1	.7
.000025	98835255	6617.8	0.	100.0	0.	97.0	1.4	1.5
.000010	148607011	7511.3	0.	100.0	0.	93.4	2.6	4.0
0.	153679135	7577.7	0.	100.0	0.	92.7	2.7	4.6

TABLE 4-14. EXPOSURE AND DOSAGE SUMMARY OF BENZYL CHLORIDE

Concentration Level (µg/m³)	Population Exposed (persons)				Dosage [(µg/m³)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
18.5	1	0	0	1	13	0	0	13
10	7	0	0	7	101	0	0	101
5	26	0	0	26	227	0	0	227
2.5	44	0	0	44	286	0	0	286
1	209	0	0	209	521	0	0	521
0.5	858	0	0	858	963	0	0	963
0.25	3,312	0	0	3,312	1,810	0	0	1,810
0.1	10,606	0	0	10,606	2,990	0	0	2,990
0.05	19,356	0	0	19,356	3,620	0	0	3,620
0.025	39,471	0	0	39,471	4,340	0	0	4,340
0.01	102,126	0	0	102,126	5,320	0	0	5,320
0.005	216,455	0	0	216,455	6,110	0	0	6,110
0.0025	449,991	0	0	449,991	6,900	0	0	6,900
0.001	1,229,667	0	0	1,229,667	8,110	0	0	8,110
0.0005	2,265,842	0	446,952	2,712,794	8,840	0	261	9,101
0.00025	4,270,619	0	505,140	4,775,759	9,530	0	289	9,819
0.0001	11,982,073	0	17,551,646	29,533,719	10,704	0	3,080	13,784
0.00005	--	0	38,996,868	--	--	0	4,550	--
0.000025	--	0	98,835,255	--	--	0	6,620	--
0.00001	--	0	148,607,011	--	--	0	7,510	--
0.0	33,270,545	0	158,679,135	--	11,600	0	7,580	19,180

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. "Chemical Product Synopsis on Benzyl Chloride," Mannsville Chemical Products, Mannsville, NY (July 1978).

2. 1979 Directory of Chemical Producers, United States, Stanford Research Institute, Menlo Park, CA.

3. "Chemical Product Synopsis on Benzyl Alcohol," Mannsville Chemical Products, Mannsville, NY (July 1978).

4. State of New Jersey, Department of Environmental Protection, Bureau of Air Pollution Control, files on Universal Oil Products, E. Rutherford, New Jersey.

5. State of New Jersey, Department of Environmental Protection, Bureau of Air Pollution Control, files on Stauffer Chemical Company, Edison, New Jersey.

6. Special Project Report, "Petrochemical Plant Sites," prepared for Industrial Pollution Control Division, Industrial Environmental Research Laboratory, Environmental Protection Agency, Cincinnati, OH, by Monsanto Research Corporation, Dayton, OH (April 1976).

APPENDIX A-5 ----- Beryllium

BERYLLIUM CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 744-04-17

Synonyms: Glucinium

Chemical Formula

Molecular Weight: 9.012 (atomic)

Molecular Formula: Be - atomic number: 4

Molecular Structure: Gray metal, close-packed hexagonal structure, anisotropic

Chemical and Physical Properties

Physical State at STP: hard, non-corrosible gray metal

Boiling Point: 2970°C at 5 mm

Melting Point: 1278°C

Density: 1.848 at 20°C/4°C

Vapor Pressure: N/A

Vapor Density: N/A

Solubility: Insoluble

Log Partition Coefficient (Octanol/H_2O): N/A

Atmospheric Reactivity

Transformation Products: (depend upon aerosol size range and growth characteristics) Metal resistant to attack by acid due to the formation of a thin oxide film.

Reactivity Toward OH·:
Reactivity Toward O_3: unreactive
Reactivity Toward Photolysis:

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

Bertrandite ore is the major source for beryllium mineral produced in the United States. Production data for beryllium have not been reported in recent years in order to avoid disclosing individual company confidential data.[1]

Only one site, Brush Wellman, Inc., in Millard County, Utah, processes bertrandite ore and converts it to beryllium hydroxide. Brush Wellman processes both domestic bertrandite ore, mined at its delta facility, and imported beryl ore for Kawecki-Berylco. The beryllium hydroxide resulting from the processing of the imported beryl ore is then upgraded by Kawecki-Berylco at its plants in Hazelton and Reading, Pennsylvania.[1,2] Small quantities of beryl ore have reportedly been mined in South Dakota and Arizona.

In 1976, the last year for which data are available, 7.5 million lb of beryllium was used in the United States. Of this quantity, approximately 2.1 million lb was imported from other countries, and the remaining 5.4 million lb was obtained from stockpiles and production.[2]

B. USES

The primary end-use of beryllium is in the manufacture of beryllium-copper alloys. An estimated 75% (5.6 million lb) is consumed for this end-use. Beryllium metal production consumed an estimated 18% (1.35 million lb), and beryllium oxide consumed the remaining 7% (0.55 million lb). Uses are summarized in Table 5-1.[2] There have been no reported exports of beryllium since 1964. Source locations for the major beryllium metal and alloy sites are shown in Table 5-2.[3,4] Total beryllium use in metal and alloy manufacture was allocated based on the number of employees at each site.

C. INCIDENTAL SOURCES

Incidental sources of beryllium emissions include coal- and oil-fired boilers, coke ovens, and the gray iron foundry industry. The boilers include industrial, power plant, commercial, and residential types. Beryllium emissions originate as impurities from oil and coal when they are burned in the boilers or in coke ovens or as diesel fuel. Table 5-3 shows the estimated consumption of oil and coal in 1978 by category. Table 5-4 indicates, by region, the percent of coal and oil used by power plants.

Table 5-1. Beryllium End-Use 1978[a]

Use	Usage (10^6 lb/yr)	Usage (%)
Beryllium-copper alloys	5.6	75
Beryllium metal	1.35	18
Beryllium-oxide ceramics	0.55	7
Total	7.5	100

[a] See ref. 2.

Table 5-2. Beryllium Metal and Alloy Producers[a]

Company	Location	Beryllium Metal/ Alloy Capacity (lb/yr)	Beryllium Used[b] (lb/yr)	Geographical Location Latitude/Longitude
Brush Wellman	Elmore, OH	NA	2.39	41 28 06/83 16 37
	Reading, PA	NA	0.57	40 46 45/73 11 10
	Hampton, NJ	NA	0.28	40 42 32/74 57 41
Kawecki Berylco Industries	Hazelton, PA	NA	2.16	40 21 28/75 57 10
	Reading, PA	NA	1.55	40 47 32/73 11 50
Total			6.95	

[a] See refs. 3 and 4.

[b] Total beryllium usage distributed over the sites based on the number of people employed.

Table 5-3. 1978 United States Oil and Coal Consumption*

User	Coal Consumption (million tons)	Oil Consumption (million bbls)
Electrical utilities	480	646
Industry	55	671
Coke ovens	75	-
Residential commercial	8	707
Diesel fuel	-	327
Total	618	2351

*See refs 5 and 6.

Table 5-4. Electrical Utility Power Plant Locations and Usage of Coal and Oil by Geographic Region*

Region	Number of Sites	Percentage of Total U.S. Coal Consumption	Number of Sites	Percentage of Total U.S. Oil Consumption
New England	9	0.7	35	9.4
Middle Atlantic	51	11.3	70	27.9
East North Central	156	33.9	110	5.9
West North Central	111	9.4	85	0.7
South Atlantic	61	19.6	97	31.4
East South Central	44	16.3	26	2.0
West South Central	3	1.3	100	4.8
Mountain	38	6.8	44	2.2
Pacific	1	0.7	33	15.7
Total	474	100.0	600	100.0

*See ref. 7.

II. EMISSION ESTIMATES

A. PRODUCTION

The primary source of emission data for this summary was the Survey of Emissions and Controls for Hazardous and Other Pollutants prepared for the Environmental Protection Agency by the Mitre Corp.[8] In this report, it is estimated that emissions resulting from ore mining and processing, use as beryllium oxide, and use in beryllium metal fabrication are negligible due to control techniques. The only significant sources of beryllium emissions are in beryllium alloy and compound manufacture and from the incidental sources noted in Section I.

B. USES

Beryllium emissions from beryllium metal and alloy manufacture are shown in Table 5-5.[3,4,8] Total emissions were derived by multiplying the emission factor of 0.000785 lb beryllium lost per lb used from the Mitre report[8] times the beryllium used. Total beryllium emissions from this end-use are estimated to have been 5455 lb.

C. INCIDENTAL

Beryllium emissions resulting from gray iron foundry operations are shown in Table 5-6 by geographic region. They totaled 8,000 lb. Emissions were estimated by multiplying the emission factor 0.000444 lb/ton[8] times the estimated production of 18,000,000 tons of metal. The total emissions were then distributed by region based on the total number of employees in gray iron foundry operations in each region.[9]

Beryllium emissions resulting from electrical utility power plants are shown for coal-fired operations in Table 5-7 and for oil-fired operations in Table 5-8. Coal-fired plants had emissions of 240,000 lb, and oil-fired plants had emissions of 9500 lb.

These emissions were calculated by multiplying the emission factors shown in Tables 5-7 and 5-8 by the coal and oil used shown in Table 5-3. The emissions were distributed by region according to the usage percentages shown in Table 5-4.

Table 5-5. Beryllium Emissions from Beryllium Metal and Allyol Production[a]

Company	Location	Beryllium Used (lb/yr)[b]	Beryllium Emissions[c]	
			(lb/yr)	(g/sec)[d]
Brush Wellman	Elmore, OH	2.39	1875	0.027
	Reading, PA	0.57	450	0.006
	Hampton, NJ	0.28	220	0.003
Kawecki-Berylco	Hazelton, PA	2.16	1695	0.024
	Reading, PA	1.55	1215	0.017
Total		6.95	5455	

---

[a] See refs. 3 and 4.

[b] Total beryllium usage allocated per site based on the number of employees at each site.

[c] Based on emission factor of 0.000785 lb beryllium lost per lb used. C - derived from published source. See ref. 8.

[d] Assumes 8760 hr/yr operation.

Table 5-6. Beryllium Emissions from Gray Iron Foundry Operations*

Region	Number of Sites	Beryllium Emissions (lb/yr)	Average Emissions/Site (lb/yr)	Average Emissions/Site (g/sec)[b]
New England	13	200	15.4	0.0002
Middle Atlantic	42	735	17.5	0.0003
East North Central	129	4170	32.3	0.0005
West North Central	29	455	15.7	0.0002
South Atlantic	22	590	26.8	0.0004
East South Central	37	944	25.5	0.0004
West South Central	19	400	21.0	0.0003
Mountain	5	95	23.8	0.0003
Pacific	28	408	14.5	0.0002
Total	324	8000[c]		

[a] See ref. 9.

[b] Based on 8760 hr/yr operation.

[c] Based on an emission factor of 0.000444 lb beryllium lost per ton of metal produced. C - derived from published data. See ref. 8.

Table 5-7. Beryllium Emissions from Electrical Utilities Power Plants Coal-fired[a]

Region	Number of Sites	Beryllium Emissions (lb/yr)	Average Emissions/Site (lb/yr)	Average Emissions/Site (g/sec)[b]
New England	9	1,680	190	0.003
Middle Atlantic	51	27,120	530	0.008
East North Central	156	81,360	520	0.007
West North Central	111	22,560	200	0.003
South Atlantic	61	47,040	770	0.011
East South Central	44	39,120	890	0.013
West South Central	3	3,120	1040	0.015
Mountain	38	16,320	430	0.006
Pacific	1	1,680	1680	0.024
Total	474	240,000[c]	506	

[a] See ref. 7.

[b] Based on 8760 hr/yr operation.

[c] Based on 0.00000025 lb beryllium emitted per lb coal burned. C - derived from published data. See ref. 8.

Table 5-8. Beryllium Emissions from Electrical Utility Power Plants Oil-fired[a]

Region	Number of Sites	Beryllium Emissions (lb/yr)	Average Emissions/Site (lb/yr)	Average Emissions/Site (g/sec)[b]
New England	35	893	25.5	0.0004
Middle Atlantic	70	2650	37.9	0.0005
East North Central	110	560	5.1	nil
West North Central	85	67	0.8	nil
South Atlantic	97	2983	30.8	0.0004
East South Central	26	190	7.3	0.0001
West South Central	100	456	4.6	nil
Mountain	44	209	4.8	nil
Pacific	33	1492	45.2	0.0007
Total	600	9500[c]	15.8	

[a] See ref. 7.

[b] Based on 8760 hr/yr operation.

[c] Based on 0.00000035 lb beryllium emitted per gallon oil burned. C - derived from published data. See ref. 8.

Beryllium emissions from coke oven operations were estimated to be 37,500 lb as shown in Table 5-9. This estimate is based on the coal emission factor derived for power plants.[8] Total emissions were distributed by the number of sites in each region.[10]

The remaining incidental sources of beryllium emissions are from other sources that burn oil or coal. The emission factors used were the same as for power plant emission estimates. Emissions from oil- and coal-fired industrial boilers were estimated to have been 27,500 lb and 9870 lb respectively. Emissions from residential and commercial oil and coal heating were estimated to be 4,000 lb and 10,400 lb respectively. Diesel fuel consumption generated an estimated 4810 lb of beryllium emissions. Source locations for all these incidental categories are considered too numerous and too diverse to pinpoint regional distributions.

Vent parameter data for all beryllium emission sources are shown in Table 5-10.

Table 5-11 presents a summary of beryllium emissions. Total nationwide beryllium emissions are estimated to have been 357,035 lb in 1978.

Table 5-9. Beryllium Emissions from Coke Oven Operations[a]

Region	Number of Sites	Beryllium Emissions (lb/yr)
New England	0	0
Middle Atlantic	15	9,220
East North Central	25	15,370
West North Central	3	1,845
South Atlantic	4	2,460
East South Central	9	5,530
West South Central	2	1,230
Mountain	2	1,230
Pacific	1	615
Total	61	37,500[b,c]

[a] See ref. 10.

[b] Based on an emission factor of 0.00000025 lb lost/lb coal burned. See ref. 8.

[c] Average emission per site 615 lb/yr (0.009 g/sec).

Table 5-10. Beryllium Vent Parameters*

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)
Power plants	1	400	16	200	90
Gray iron foundry	1	150	2	200	40
Alloy manufacture	2	40	1	140	10
Coke oven	2	30	1	300	15

*Building cross-section for all sources - 200 m^2.

Table 5-11. 1978 Beryllium Nationwide Emissions

Source	Estimated Nationwide Emissions (lb/yr)
Producers	Negligible
Beryllium metal, alloys, and compounds	5,455
Beryllium fabrication	Negligible
Beryllium oxide-ceramics	Negligible
Gray iron foundries	8,000
Electrical utility	
Power plant boilers	
Coal	240,000
Oil	9,500
Industrial boilers	
Coal	27,500
Oil	9,870
Residential/commercial boilers	
Coal	4,000
Oil	10,400
Coke ovens (coal)	37,500
Diesel fuel (oil)	4,810
Total	357,035

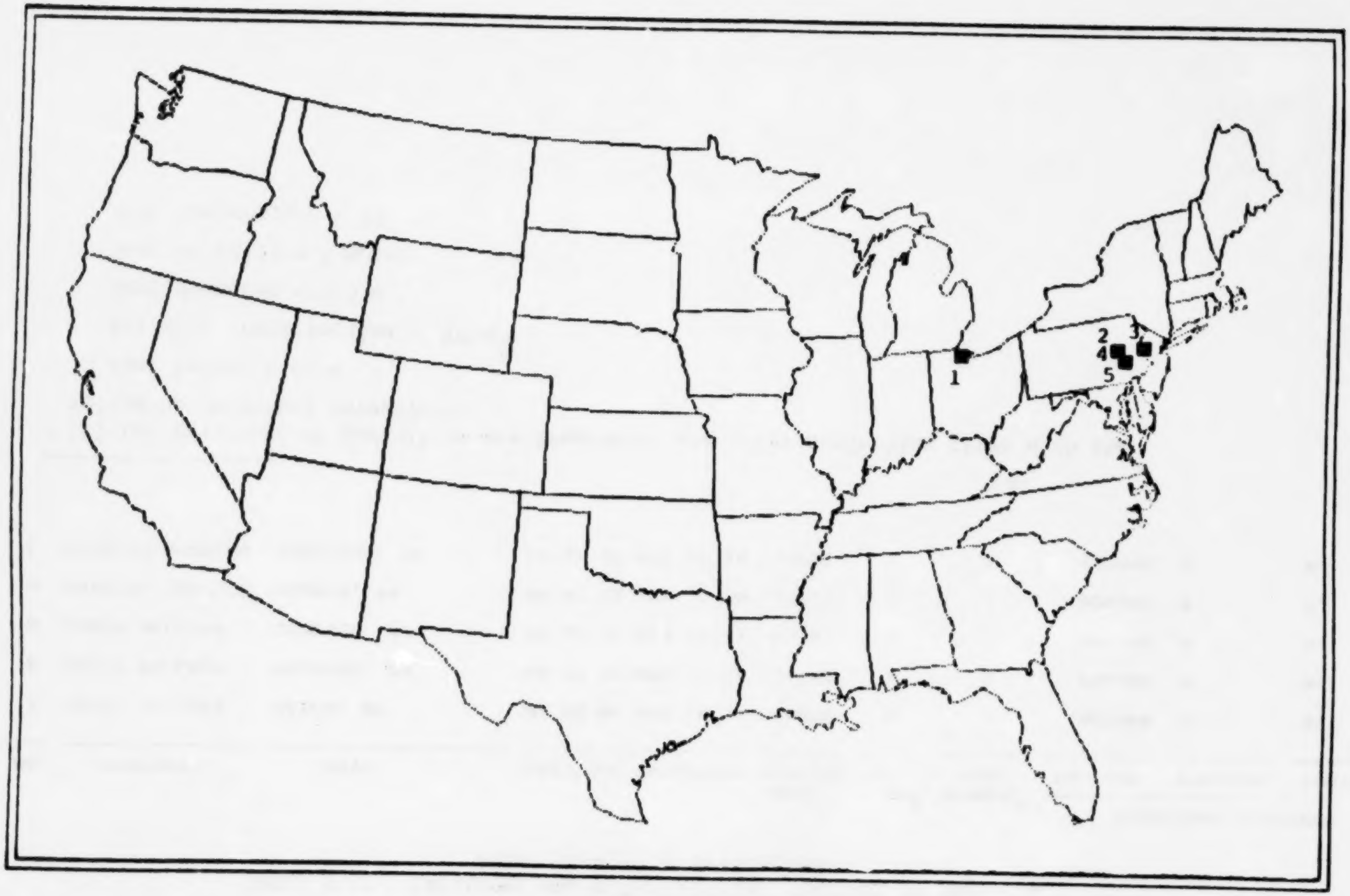


FIGURE 5-1. SPECIFIC POINT SOURCES OF BERYLLIUM EMISSIONS

TABLE 5-12. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF BERRYLLIUM

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE* TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	BRUSH WELLMAN	ELMOR, OH	41 28 06	083 16 37	94830	1	1	.027000	0.	0.
2	BRUCH WELLMAN	READING, PA	40 46 45	076 11 10	14712	1	1	.006480	0.	0.
3	BRUSH WELLMAN	HAMPTON, NJ	40 42 32	074 57 41	94741	1	1	.003168	0.	0.
4	KAWECKI-BERYLCO	READIN, PA	40 47 32	076 11 50	14712	1	1	.024408	0.	0.
5	KAWECKI-BERYLCO	HAZELTON, PA	40 21 28	075 57 10	14737	1	1	.017496	0.	0.

---

* All the emissions of berryllium are from metal and alloy production sites with the following emissions parameters:

Vent height = 12 m

Building cross-section = 200 m^2

Vent diameter = 0.3 m

Vent velocity = 3 m/sec

Vent temperature = 333 °K

TABLE 5-13. EXPOSURE AND DOSAGE OF BERYLLIUM RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
0.394	0	.132
0.25	71	18.6
0.1	795	126
0.05	2,387	235
0.025	5,794	346
0.01	23,622	585
0.005	61,062	849
0.0025	117,129	1,050
0.001	275,165	1,300
0.0005	367,850	1,370
0.0025	494,748	1,420
0.0001	619,837	1,440
8.01×10^{-6}*	720,769	1,440

---

*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 5-14. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF BERYLLIUM

Region	Gray Iron Foundry		Power Plant (Coal)		Power Plant (Oil)		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00022	13	0.00274	9	0.00037	35	0	0
Middle Atlantic	0.00025	42	0.00763	51	0.00055	70	0.00885	15
East North Central	0.00047	129	0.00749	156	0.000073	110	0.00885	25
West North Central	0.00023	29	0.00288	111	0.000012	85	0.00885	3
South Atlantic	0.00039	22	0.0111	61	0.00044	97	0.00885	4
East South Central	0.00037	37	0.0128	44	0.00011	26	0.00885	9
West South Central	0.00030	19	0.0150	3	0.000066	100	0.00885	2
Mountain	0.00034	5	0.0062	38	0.000069	44	0.00885	2
Pacific	0.00021	28	0.00242	1	0.00065	33	0.00885	1

TABLE 5-15. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF BERYLLIUM

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)					Dosage [$10^3(\mu g/m^3)\cdot$persons]				
	Gray Iron Foundry	Power Plant (Coal)	Power Plant (Oil)	Coke Oven	U.S. Total	Gray Iron Foundry	Power Plant (Coal)	Power Plant (Oil)	Coke Oven	U.S. Total
0.5	0	0	0	0.127	0.127	0	0	0	0.08	0.08
0.25	0	0	0	4.37	4.37	0	0	0	1.6	1.6
0.10	0	0	0	27.5	27.5	0	0	0	5.0	5
0.05	0	0	0	70.3	70.3	0	0	0	8	8
0.025	0	0	0	181	181	0	0	0	11.6	11.6
0.010	0	27	0	702	729	0	0.4	0	18.8	19.2
0.005	0	538	0	1,620	2,160	0	3.7	0	24.8	28.5
0.0025	0	1,800	0	3,170	4,970	0	8.2	0	30.2	38.4
0.0010	--	--	--	--	--	0.04	20	0	38.5	58.9
0.0005	--	--	--	--	--	0.3	29	0	47.2	76.5
0.00025	--	--	--	--	--	1.1	38	0.4	56.5	96.1
0	--	--	--	--	--	7.4	82	3.2	67.4	160

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 5-16. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF BERYLLIUM

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0.203 gm/sec
Residential/commercial coal burning	0.058 gm/sec
Residential/commercial oil burning	0.145 gm/sec
Nationwide nonheating stationary source emissions (E_N)	0.538 gm/sec
Coal-burning	0.396 gm/sec
Oil-burning	0.142 gm/sec
Nationwide mobile source emissions (E_M)	0.0693 gm/sec
Ratio of truck emissions to auto emissions (R_M)	3.0

TABLE 5-17. BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.002500	505140	1750.9	13.8	82.4	3.8	100.0	0.	0.
.001000	9149730	16754.3	30.8	66.6	2.6	100.0	0.	0.
.000500	28601329	30552.2	28.9	66.7	4.4	100.0	0.	0.
.000250	73351092	45256.6	27.7	67.2	5.1	97.8	.8	1.3
.000100	139664758	56042.5	26.9	67.4	5.8	94.2	2.5	3.3
0.	158679135	53136.8	26.8	67.4	5.8	92.8	2.6	4.6

TABLE 5-18. EXPOSURE AND DOSAGE SUMMARY OF BERYLLIUM

Concentration Level (μg/m^3)	Population Exposed (persons)				Dosage [(μg/m^3)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
0.5	0	127	0	127	0	80	0	80
0.25	71	4,370	0	4,441	19	600	0	619
0.1	795	27,500	0	28,295	126	5,000	0	5,126
0.05	2,387	70,300	0	72,687	235	8,000	0	8,235
0.025	5,794	181,000	0	186,794	346	11,600	0	11,946
0.01	23,622	729,000	0	752,622	585	19,200	0	19,785
0.005	61,062	2,160,000	0	2,221,062	849	28,500	0	29,349
0.0025	117,129	4,970,000	505,140	5,592,269	1,050	38,400	1,759	41,259
0.001	275,165	--	9,149,730	--	1,300	58,900	16,754	76,954
0.0005	367,850	--	28,601,329	--	1,370	76,500	30,552	107,052
0.00025	494,748	--	73,351,092	--	1,420	96,000	45,257	--
0.0001	619,837	--	139,664,758	--	1,440	--	56,843	--
0	720,769	--	158,679,135	--	1,440	160,000	58,100	219,600

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. Benjamin Petkof, "Beryllium," Bureau of Mines Minerals Yearbook, 1976.

2. "Beryllium Minerals—Salient Characteristics," Chemical Economics Handbook, p. 716.1000A, Stanford Research Institute, Menlo Park, CA (July 1978).

3. 1978 Directory of Chemical Producers, United States, p. 474, Stanford Research Institute, Menlo Park, CA.

4. 1979 Thomas Register, Thomas Publishing Co., New York, NY.

5. "Bituminous Coal," Chemical Economics Handbook, p. 211.3026, Stanford Research Institute, Menlo Park, CA (October 1978).

6. "Fuel Oils," Chemical Economics Handbook, p. 229.4350B, Stanford Research Institute, Menlo Park, CA (February 1979).

7. "Existing Power Plants as of 1974," supplied by Systems Applications, Inc., San Rafael, CA, to Hydroscience, Inc., Knoxville, TN.

8. Survey of Emissions and Controls for Hazardous and Other Pollutants, the Mitre Corp., EPA Contract No. 68-01-0438, p. 103.

9. Marketing Economics Key Plants 1975-1976, Marketing Economics Institute, New York, New York.

10. "Coke Oven Plants in the United States," p. 212.2000A—D, Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (October 1978).

APPENDIX A-6 ----- Carbon Tetrachloride

CARBON TETRACHLORIDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 56-23-5

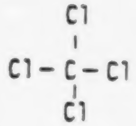
Synonyms: Tetrachloromethane; Perchloromethane; Methane Tetrachloride; Necatorina; Benzinoform

Chemical Formula

Molecular Weight: 153.82

Molecular Formula: CCl_4

Molecular Structure:



$$\begin{array}{c} Cl \\ | \\ Cl-C-Cl \\ | \\ Cl \end{array}$$

Chemical and Physical Properties

Physical State at STP: Liquid - colorless, nonflammable

Boiling Point: 76.54°C at 760 mm

Melting Point: -22.99°C

Density: 1.5940 at 20°C/4°C

Vapor Pressure: 115.2 mm at 25°C

Vapor Density: 5.32

Solubility: Soluble (0.77 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.64

Atmospheric Reactivity

Transformation Products: None - NAPP

Reactivity Toward OH·: Extremely slow

Reactivity Toward O_3: Extremely slow

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: Chlorinated hydrocarbons

Formation Reactivity:

I. SOURCES

Four volatile organic compounds——methyl chloride, methylene chloride, chloroform, and carbon tetrachloride——comprise the group of chemicals commonly referred to as the chloromethanes.

Carbon tetrachloride (CCl_4) can be produced by a variety of processes including the chlorination of carbon disulfide, methane, and methyl chloride, or the chlorinolysis of mixed hydrocarbons.

In 1978 six companies at ten locations in the U.S. produced an estimated 750 million lb of carbon tetrachloride. The locations of the plants, the type of production process used, and the 1978 capacity and estimated production level for each plant are shown in Table 6-1.[4,8,9]

The major end-use for carbon tetrachloride is in the production of the fluorocarbon gases trichlorofluoromethane (F-11) and dichlorodifluoromethane (F-12). An estimated 55% (412.5 million lb) of carbon tetrachloride was used to make F-12 and an estimated 255.0 million lb was used to make F-11 in 1978.

The remaining carbon tetrachloride production (60.0 million lb) was used in solvent applications as an oil, wax, and fat extractant; in rubber cement; in shoe and furniture polishes; in paints and lacquers; in printing ink; in floor waxes; in stains; and in pesticide manufacture.

An estimated 3% of the total production amounting to 22.5 million lb of carbon tetrachloride was exported. End-uses for carbon tetrachloride are summarized in Table 6-2.[6]

II. EMISSION ESTIMATES

PRODUCTION

Estimated emission losses from the production of carbon tetrachloride for each location is shown in Table 6-3.[1,2] Total emissions of methylene chloride, chloroform, and carbon tetrachloride from production facilities are estimated to have been 1,351,580 lb, 351,280 lb, and 4,557,160 lb respectively in 1978. These estimates are based on the emission factors generated for each of the four processes used in the industry.[1,2,10] Other associated emission components include methyl chloride and hydrogen chloride from the methyl chloride and methane chlorination processes and perchloroethylene, ethylene source locations

TABLE 6-1. Production of Carbon Tetrachloride[a]

Source[b]	Location	1978 Estimated Production[c] (10^6 lb/yr)	Process[d]	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Allied Chemical Corp.	Moundsville, WV	4	A,B[c]	8	39 54 24/80 47 51
Dow Chemical	Freeport, TX	70	B	135	28 59 15/95 24 45
	Pittsburg, CA	42	C	80	37 59 34/121 54 56
	Plaquemine, LA	65	C	125	30 19 00/91 15 00
Du Pont	Corpus Christi, TX	213	C	410	27 53 00/97 15 00
FMC Corp.	S. Charleston, WV	156	D	300	38 22 10/81 40 03
Stauffer Chemical	LeMoyne, AL	104	D	200	30 53 50/87 58 50
	Louisville, KY	18	C	35	38 12 09/85 51 49
Vulcan Materials Co.	Geismar, LA	47	C	90	30 10 00/90 59 00
	Wichita, KS	31	C	60	37 36 55/97 18 30
Total		750		1443	

[a] See refs. 4, 8, and 9.

[b] FMC Corp. has announced that it is shutting down its 300 million pound per year plant in S. Charleston, WV, in September 1979.

[c] Distribution of the 750 million pounds per year for each producing location has been made as a direct ratio of total production/total capacity X plant capacity.

[d] (A) - Methyl chloride chlorination.
(B) - Methane chlorination.
(C) - Chlorinolysis of mixed HC feed with perchlor co-product.
(D) - Carbon disulfide chlorination.

[e] 5% methane chlorination, 95% methyl chloride chlorination.

TABLE 6-2. 1978 Carbon Tetrachloride Consumption by End Use*

End Use	Percent of Total Consumption	End Use Consumption (M lb)
Dichlorodifluoromethane (F-12)	55	412.5
Trichlorofluoromethane (F-11)	34	255.0
Solvents and miscellaneous	8	60.0
Export	3	22.5
Total	100	750.0

*See ref. 6.

TABLE 6-3. 1978 Carbon Tetrachloride Production Emissions

Company	Location	Process Vent Emissions (lb/yr)	Process Vent Emissions (g/sec)[b]	Storage Vent Emissions (lb/yr)	Storage Vent Emissions (g/sec)[b]	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)[b]	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Allied Chemical	Moundsville, WV	20	Nil	510	0.007	290	0.004	820	0.012
Dow Chemical	Freeport, TX	370	0.005	8,880	0.128	5,030	0.072	14,280	0.206
	Pittsburg, CA	350	0.005	70,140	1.010	20,580	0.296	91,070	1.311
	Plaquemine, LA	550	0.008	108,550	1.563	31,850	0.459	140,950	2.029
Dupont	Corpus Christi, TX	1,790	0.026	355,710	5.121	104,370	1.503	461,870	6.649
FMC	South Charleston, WV	1,560,000	22.458	530,400	7.636	93,600	1.347	2,184,000	31.441
Stauffer	Lemoyne, AL	1,040,000	14.972	353,600	5.091	62,400	0.898	1,456,000	20.961
	Louisville, KY	150	0.002	30,060	0.433	8,820	0.127	39,030	0.562
Vulcan	Geismar, LA	400	0.006	78,490	1.130	23,030	0.332	101,920	1.467
	Wichita, KA	260	0.004	51,770	0.745	15,190	0.219	67,220	0.968
Total		2,603,890		1,588,110		365,160		4,557,160	

[a] Derived from the emission factors shown in Table 10.

[b] Based on 8760 hr/yr operation.

source locations for fluorocarbons 11 and 12 manufacture are shown in Table 6-4.[13] Also shown in that table are the production quantities for fluorocarbons 11 and 12 and the corresponding carbon tetrachloride manufacturing requirement.

Emission estimates of carbon tetrachloride from these sites are shown in Table 6-5.[14] Total estimated emissions of carbon tetrachloride from fluorocarbon 11 and 12 production sites are estimated to have been 446,200 lb in 1978. Other associated emissions from these sites would incude other halocarbons used as feed materials and the various fluorocarbons produced. Vent parameter data relative to carbon tetrachloride emissions from fluorocarbons 11 and 12 production are shown in Table 9-7. Carbon tetrachloride emissions originate from two process distillation vents and four storage tanks.

The remaining carbon tetrachloride (60.0 million lb) consumed for solvent applications is eventually released to the atmosphere. Specific source locations could not be identified. Emissions from exports were assumed to be negligible.

Total nationwide emissions of carbon tetrachloride in 1978 from all sources are estimated to have been 65,030,000 lb. A tabulation of the losses is shown in Table 6-6.

Table 6-4. Users of Carbon Tetrachloride and Chloroform to Produce Fluorocarbons

	Flurorocarbon Annual Capacity (10^6 lb)	Estimated 1978 Production			Estimated Production Totals (10^6 lb)	Carbon Tetrachloride Used (10^6 lb)	Chloroform Used (10^6 lb)	Geographic Coordinates Latitude/Longitude
		F-11 (10^6 lb)	F-12 (10^6 lb)	F-22 (10^6 lb)				
Allied Chemical								
Baton Rouge, LA	310	Assumed shut down						
Danville, IL		28.5	40.6		282.9	87.3		40 08 30/87 33 45
Elizabeth, NJ		28.5	40.6	37.8		87.3	55.7	40 40 45/74 13 51
El Segundo, CA		28.5	40.6	37.8		87.3	55.7	33 56 30/118 26 35
Du Pont								
Antioch, CA	400	36.8	52.3		364.9	112.6		37 59 37/121 52 00
Deepwater, N[illegible]		36.8	52.3	48.8		112.6	71.9	39 41 25/75 30 35
Montague, MI		36.8	52.3			112.6		43 24 10/86 23 40
Louisville, KY				48.8			71.9	38 11 51/85 54 13
Corpus Christi, TX								27 53 00/97 15 00
Pennwalt Corp.								
Calvert City, KY	80	22.1	31.4	19.5	73.0	67.6	28.6	37 03 18/88 19 40
Thorofare, NJ	35	Assumed shutdown						
Union Carbide								
Institute and S. Charleston, WV	Not listed	Assumed shutdown						
Essex Chemical Corp. (Racon)								
Wichita, KS	20							
Kaiser Aluminum & Chemical Corp.								
Gramercy, LA	80							
Total	925	218	310.1	192.7	720.8	667.5	283.8	

*See ref. 13.

Table 6-5. Emissions from Carbon Tetrachloride and Chloroform Users for Flurocarbon Production[a]

Source	Location	F-11/F-12 Carbon Tetrachloride Emissions		F-22 Chloroform Emissions	
		(lb/yr)[b]	(g/sec)[d]	(lb/yr)[c]	(g/sec)[d]
Allied	Danville, IL	58,460	0.84	0	
	Elizabeth, NJ	58,460	0.84	115,200	1.66
	El Segundo, CA	58,460	0.84	115,200	1.66
Du Pont	Antioch, CA	75,420	1.09	0	0
	Deepwater, NJ	75,420	1.09	148,800	2.14
	Montague, MI	75,420	1.09	0	0
	Louisville, KY	0		148,800	2.14
Pennwalt	Calvert City, KY	45,240	0.65	59,410	0.86
Total		446,200		587,410	

[a] See ref. 14.

[b] Based on the following emission factor:

Process	0.000449	A - (derived from site visit)
Storage	0.000442	A - (derived from site visit)
Fugitive	0.000178	A - (derived from site visit)
	0.001069	

[c] Based on the following emission factor:

Process	0	A - (derived from site visit)
Storage	0.00374	A - (derived from site visit)
Fugitive	0.00075	A - (derived from site visit)
	0.00449	

[d] Assumes 8760 hours/year operation.

Table 6-6. 1978 Estimated Carbon Tetrachloride Nationwide Emission Losses

Source	Estimated National Emission ($\bar{M}$ lb/yr)
Production	4.56
Dichlorodifluoromethane (F-12) Trichlorofluoromethane	0.47
Solvents, miscellaneous	60.0
Export	0
Total	65.03

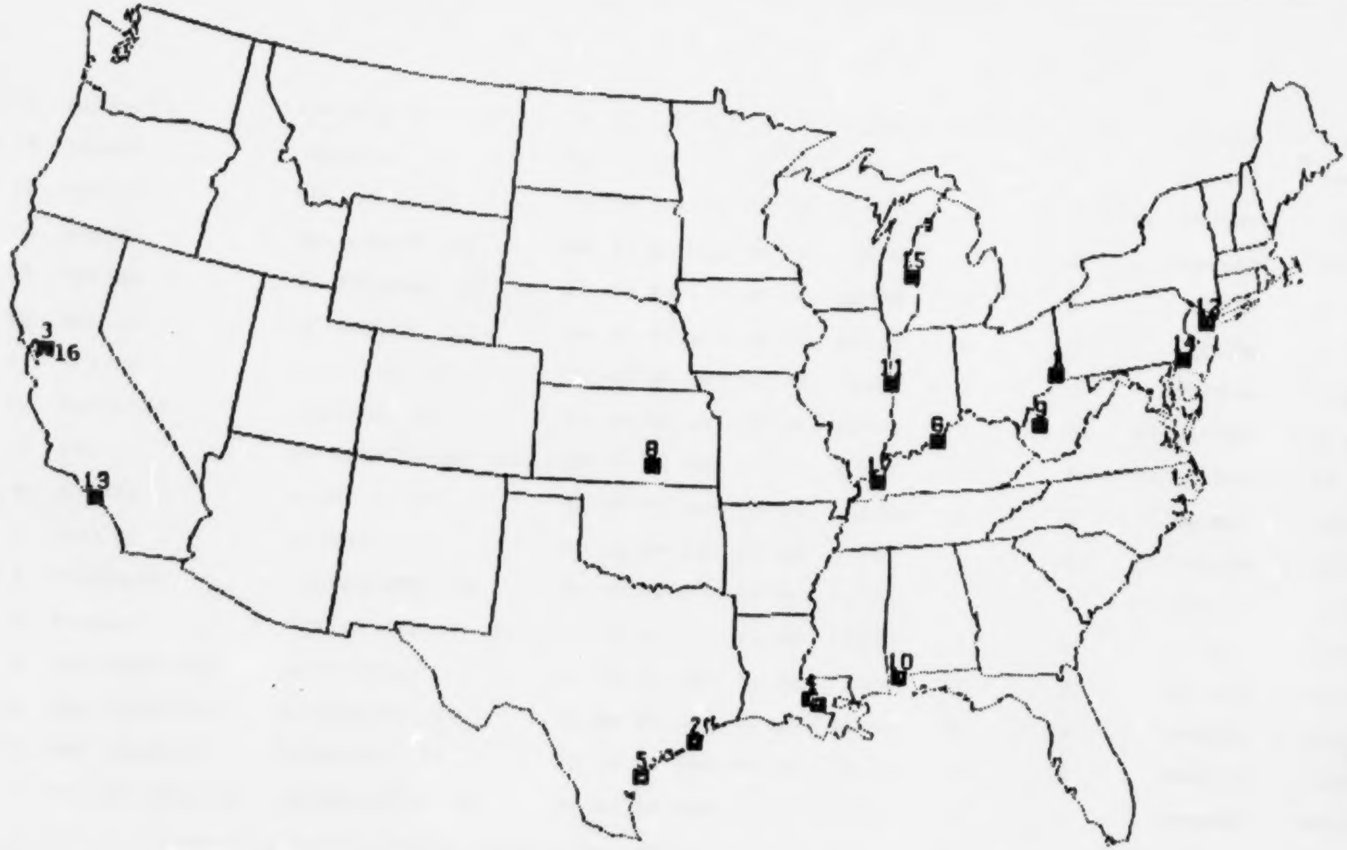

3
16
13
8
2
5
10
15
6

FIGURE 6-1. SPECIFIC POINT SOURCES OF CARBON TETRACHLORIDE EMISSIONS

TABLE 6-7. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF CARBON TETRACHLORIDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	ALLIED CHEMICAL	MOUNDSVILLE, MV	39 54 39	080 44 49	13736	1	1	.000288	.007344	.004176
2	DOW CHEMICAL	FREEPORT, TX	28 59 32	095 23 35	12923	2	2	.005328	.127872	.072432
3	DOW CHEMICAL	PITTSBURG, CA	37 59 34	121 54 56	23202	3	3	.005040	1.010016	.296352
4	DOW CHEMICAL	PLAQUEMINE, LA	30 19 00	091 15 00	13970	3	3	.007920	1.563120	.458640
5	DUPONT	CORPUS CRISTI, TX	27 53 00	097 15 00	12925	3	3	.025776	5.122224	1.502928
6	STAUFFER	LOUISVILLE, KY	38 12 09	085 51 49	93820	3	3	.002160	.432864	.127008
7	VULCAN	GEISMAR, LA	30 10 00	090 59 00	12958	3	3	.005760	1.130256	.331632
8	VULCAN	WICHITA, KA	37 36 55	097 18 30	03928	3	3	.003744	.745488	.218736
9	FMC	SO CHARLESTON, WV	38 22 10	081 40 03	13866	4	4	22.464000	7.637760	1.347840
10	STAUFFER	LEMOYNE, AL	30 53 50	087 58 50	93841	4	4	14.976000	5.091840	.898560
11	ALLIED	DANVILLE, IL	40 08 30	087 33 45	14806	5	5	.353520	.348048	.139680
12	ALLIED	ELIZABETH, NJ	40 40 45	074 13 51	04739	5	5	.353520	.348048	.139680
13	ALLIED	EL SEGUNDO, CA	33 56 30	118 26 35	23129	5	5	.353520	.348048	.139680
14	DUPONT	DEEPWATER, NJ	39 41 25	075 30 35	13739	5	5	.456192	.448992	.180864
15	DUPONT	MONTAGUE, MI	43 24 10	086 23 40	14840	5	5	.455040	.448992	.180864
16	DUPONT	ANTIOCH, CA	37 59 37	121 52 00	23202	5	5	.456192	.448992	.180864
17	PENNWALT	CALVERT CITY, KY	37 03 18	088 19 40	03816	5	5	.273600	.269280	.108432

TABLE 6-7 (Concluded)

---

* Plant Types:

Type 1: Plant produces carbon tetrachloride by using the methyl chloride chlorination process

Type 2: Plant produces carbon tetrachloride by using the methane chlorination process

Type 3: Plant produces carbon tetrachloride by using the chlorinolysis process

Type 4: Plant produces carbon tetrachloride by using the carbon disulfide chlorination process

Type 5: Plant produces flurocarbons

† Source Types:

Type 1: Methyl chloride chlorination process

Type 2: Methane chlorination process

Type 3: Chlorinolysis process

Type 4: Carbon disulfide chlorination processes

Type 5: Flurocarbons production process

TABLE 6-8. EXPOSURE AND DOSAGE OF CARBON TETRACHLORIDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
1,580	15	24,100
1,000	97	127,000
500	475	399,000
250	1,098	627,000
100	3,803	1,020,000
50	7,409	1,270,000
25	18,319	1,650,000
10	36,196	1,930,000
5	61,634	2,110,000
2.5	102,689	2,260,000
1	209,428	2,420,000
0.5	335,559	2,500,000
8.79×10^{-5}*	7,979,115	2,880,000

---

*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 6-9. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF CARBON TETRACHLORIDE

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	864 gm/sec
Nationwide mobile source emissions	0

TABLE 6-10. **CARBON TETRACHLORIDE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS**

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
2.500000	808140	2327358.7	0.	100.0	0.	100.0	0.	0.
1.000000	9149730	17913784.0	0.	100.0	0.	100.0	0.	0.
.500000	33072205	35194859.0	0.	100.0	0.	100.0	0.	0.
.250000	83219704	51528284.4	0.	100.0	0.	98.1	.7	1.2
.100000	142928535	61079083.9	0.	100.0	0.	94.0	2.5	3.5
0.	158679135	62926289.6	0.	100.0	0.	92.9	2.6	4.5

TABLE 6-12. EXPOSURE AND DOSAGE SUMMARY OF CARBON TETRACHLORIDE

Concentration Level (μg/m³)	Population Exposed (persons)				Dosage [(μg/m³)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
1580	15	0	0	15	24,100	0	0	24,100
1000	97	0	0	97	127,000	0	0	127,000
500	475	0	0	475	399,000	0	0	399,000
250	1,098	0	0	1,098	627,000	0	0	627,000
100	3,803	0	0	3,803	1,020,000	0	0	1,020,000
50	7,409	0	0	7,409	1,270,000	0	0	1,270,000
25	18,819	0	0	18,819	1,650,000	0	0	1,650,000
10	36,196	0	0	36,196	1,930,000	0	0	1,930,000
5	61,634	0	0	61,634	2,110,000	0	0	2,110,000
2.5	102,689	0	505,140	606,829	2,260,000	0	2,327,400	4,587,400
1	209,428	0	9,149,730	9,359,158	2,420,000	0	17,913,784	20,333,784
0.5	335,559	0	33,072,205	33,407,764	2,500,000	0	35,194,859	--
0.25	--	0	83,219,704	--	--	0	51,528,284	--
0.1	--	0	142,928,535	--	--	0	61,879,083	--
0	7,979,115	0	158,679,135	--	2,880,000	0	62,926,300	65,806,200

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. F. D. Hobbs and C. W. Stuewe, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Chloromethanes, Methane Chlorination Process (on file at EPA, ESED, Research Triangle Park, NC (January 1979).

2. F. D. Hobbs and C. W. Stuewe, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Chloromethanes, Methanol Hydrochlorination and Methyl Chloride Chlorination Processes (on file at EPA, ESED, Research Triangle Park, NC (January 1979).

3. "Chemical Product Synopsis on Methylene Chloride," Mannsville Chemical Products (March 1978).

4. T. E. Killilea, "Chlorinated Methanes," Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (April 1979).

5. "Chemical Profile on Methylene Chloride," Chemical Marketing Reporter (September 20, 1976).

6. "Chemical Product Synopsis on Chloroform," Mannsville Chemical Products (June 1978).

7. "Chemical Profile on Chloroform," Chemical Marketing Reporter (September 27, 1976).

8. "Chemical Product Synopsis on Carbon Tetrachloride," Mannsville Chemical Products (June 1978).

9. "Chemical Profile on Carbon Tetrachloride," Chemical Marketing Reporter (April 10, 1978).

10. F. D. Hobbs and C. W. Stuewe, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Carbon Tetrachloride and Perchloroethylene, Hydrocarbon Chlorinolysis Process (on file at EPA, ESED, Research Triangle Park, NC (March 1979).

11. Control of Volatile Organic Emissions from Solvent Metal Cleaning, EPA-450/2-77-022 (OAQPS No. 1.2-079), Research Triangle Park, NC (November 1977).

12. Solvent Metal Cleaning, Background Information: Proposed Standards (draft) EPA, NSPS, ESED, Research Triangle Park, NC (November 1978).

13. Chemical Research Services, 1979 Directory of Chemical Producers, United States of America, Stanford Research Institute, Menlo Park, CA.

14. D. M. Pitts, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry—Product Report on Fluorocarbons, on file at EPA, ESED, Research Triangle Park, NC (February 1979).

APPENDIX A-7 ----- Chlorobenzene (p-Dichlorobenzene and o-Dichlorobenzene)

CHLOROBENZENE (MONO) CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 108-90-7

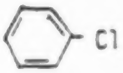
Synonyms: Phenyl Chloride; Monochlorobenzene; Chorobenzol; Benzene Chloride

Chemical Formula

Molecular Weight: 112.56

Molecular Formula: C_6H_5Cl

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid-colorless, very refractive

Boiling Point: 131.7°C at 760 mm

Melting Point: -45.6°C

Density: 1.1053 at 20°C/4°C

Vapor Pressure: 12.14 mm at 25°C

Vapor Density: 3.88

Solubility: Insoluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.84

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 1/3 Butane

Reactivity Toward O_3: No reaction

Reactivity Toward Photolysis: No photochemical degradation

Major Atmospheric Precursors: N/A

Formation Reactivity:

o-DICHLOROBENZENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 95-50-1

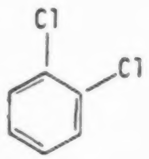
Synonyms: DCB; Dichlorobenzol; 1,2-Dichlorobenzene; o-Dichlorobenzol; ODB; ODCB; Chloroben; Cloroben; Dizene; Dowthern E

Chemical Formula

Molecular Weight: 147.0

Molecular Formula: $C_6H_4Cl_2$

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - colorless

Boiling Point: 180.5°C at 760 mm

Melting Point: -17°C

Density: 1.305 at 20°C/4°C

Vapor Pressure: 1.45 at 25°C

Vapor Density: 5.05

Solubility: Slightly soluble (0.145 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 3.38

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 1/2 Butane

Reactivity Toward O_3: 5% Propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

p-DICHLOROBENZENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 95-50-1

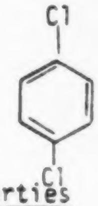
Synonyms: DCB; Dichlorobenzol; Paradichlorobenzene; Parazene; Paramoth; Di-chloricide; Paracide; Paradi; Paradow; Santochlor

Chemical Formula

Molecular Weight: 147.0

Molecular Formula: $C_6H_4Cl_2$

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Monoclinic crystals - volatile

Boiling Point: 174.12°C

Melting Point: 53.5°C

Density: 1.288 at 20°C/4°C

Vapor Pressure: 2.28 at 25°C

Vapor Density:

Solubility: Nearly insoluble (0.079 g/1 of H_2O)

Log Partition Coefficient (Octanol/H_2O): 3.39

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 1/2 Butane

Reactivity Toward O_3: 5% Propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

This report summarizes emissions of chlorobenzenes including monochlorobenzene and the two dichlorobenzene isomers (o-dichlorobenzene and p-dichlorobenzene). Monochlorobenzene is produced by the direct chlorination of benzene using iron as a catalyst. When only monochlorobenzene is desired, the temperature is kept near the lower end of a 40 to 60°C range, and only 60% of the theoretical amount of chlorine is added to lessen the formation of dichlorobenzenes. When dichlorobenzenes are desired, higher chlorine quantities and temperatures are used. The chlorinated benzene is neutralized with aqueous caustic soda, allowed to separate, and the dichlorobenzene-rich sludge that forms is removed. The chlorobenzene layer is then distilled to obtain a fraction containing unreacted benzene and some monochlorobenzene, which is recycled, and chlorobenzene. The higher chlorinated fractions and residues from a number of batches are combined and then distilled to recover para-dichlorobenzene in the distillate and ortho-dichlorobenzene residues which are then purified.

There are currently 6 monochlorobenzene producers in the United States. The locations of the plants and the 1978 capacity and estimated production for each plant are shown in Table 7-1.[1] [2] [3] In 1978, an estimated 355 million lb of monochlorobenzene was produced.

Table 7-2 [3] [4] [5] presents the producers of o-dichlorobenzene in the United States. There are currently 7 sites which produced an estimated 59 million lb of o-dichlorobenzene in 1978.

Table 7-3 [3] [4] [6] presents the producers of p-dichlorobenzene in the United States. There are currently 7 sites which produced an estimated 55 million lb of p-dichlorobenzene in 1978.

B. USES

Table 7-4 summaries the chlorobenzene end-use distribution. The various uses, quantities, and percent usage of monochlorobenzene, o-dichlorobenzene, and p-dichlorobenzene are shown. Approximately 49% of the monochloobenzene produced is used in solvents and 30% is used in nitrochlorobenzenes. Other uses

Table 7-1. Monochlorobenzene Producers[a]

Source	Location	1978 Estimated Production[b] (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Dow	Midland, MI	101	220	43 35 28/84 13 08
ICC	Niagra Falls, NY	5	10	43 03 33/79 00 55
Monsanto	Sauget, IL	69	150	38 35 31/90 10 11
Montrose	Henderson, NV	32	70	36 03 32/114 58 34
PPG[b]	New Martinsville, WV	79	172	39 47 22/80 51 27
Standard Chlorine	Delaware City, DE	69	150	39 33 54/75 38 47
Total		355	772	

[a] See refs. 1, 2, and 3.

[b] Total production was distributed per site based on site capacity.

Table 7-2. o-Dichlorobenzene Producers[a]

Source	Location	1978 Estimated Production[b] (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Dow	Midland, MI	12	30	43 35 28/84 13 08
Monsanto	Sauget, IL	6	16	38 35 31/90 10 11
PPG	New Martinsville, WV	15	38	39 47 22/80 51 27
Standard Chlorine	Delaware City, DE	19	50	39 33 54/75 38 47
Specialty Organics[c]	Irwindale, CA	1	2	34 06 30/117 55 48
Montrose	Henderson, NV	3	7	36 03 32/114 58 34
ICC	Niagara Falls, NY	3	8	43 03 33/79 00 55
Total		59	151	

[a] See refs. 3, 4, and 5.

[b] Total production was distributed per site based on capacity.

[c] Processes dichlorobenzenes from Montrose.

Table 7-3. p-Dichlorobenzene Producers[a]

Source	Location	1978 Estimated Production[b] (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Dow	Midland, MI	9	30	43 35 28/84 13 08
Monsanto	Sauget, IL	4	12	38 35 31/90 10 11
PPG	New Martinsville, WV	13	40	39 47 22/80 51 27
Standard Chlorine	Delaware City, DE	24	75	39 33 54/75 38 47
Specialty Organics[c]	Irwindale, CA	1	2	34 06 30/117 55 48
Montrose	Henderson, NV	2	7	36 03 32/114 58 34
ICC	Niagara Falls, NY	2	8	43 03 33/79 00 55
Total		55	174	

[a] See refs. 3, 4, and 6.

[b] Total production was distributed per site based on capacity.

[c] Processes dichlorobenzenes from Montrose.

Table 7-4. Chlorobenzenes End-Use Distribution 1978[a]

Source	Usage (million lb/yr)	Usage (%)
Monochlorobenzene	355	10C
Pesticide/degreasing solvents	174	49
Nitrochlorobenzene	107	30
DDT	25	7
Diphenyl oxide	28	8
Miscellaneous, others	21	6
o-Dichlorobenzene	59	100
3,4 dichloroaniline	38	65
Toluene diisocyanate solvent	9	15
Miscellaneous solvents (paint removers, engine cleaners, etc.)	6	10
Dye manufacturing	3	5
Pesticide intermediate	3	5
p-Dichlorobenzene	55	100
Space deodorant	27.5	50
Moth control	22	40
Pesticide intermediate	5.5	10

[a] See ref. 3.

Table 7-4. Chlorobenzenes End-Use Distribution 1978[a]

Source	Usage (million lb/yr)	Usage (%)
Monochlorobenzene	355	100
Pesticide/degreasing solvents	174	49
Nitrochlorobenzene	107	30
DDT	25	7
Diphenyl oxide	28	8
Miscellaneous, others	21	6
o-Dichlorobenzene	59	100
3,4 dichloroaniline	38	65
Toluene diisocyanate solvent	9	15
Miscellaneous solvents (paint removers, engine cleaners, etc.)	6	10
Dye manufacturing	3	5
Pesticide intermediate	3	5
p-Dichlorobenzene	55	100
Space deodorant	27.5	50
Moth control	22	40
Pesticide intermediate	5.5	10

[a] See ref. 3.

of monochlorobenzene include DDT and diphenyl oxide. Approximately 65% of the o-dichlorobenzene produced is used for dichloroaniline manufacture, which is then used as an intermediate in pesticide manufacture. Other uses include solvents, dyes, and as a pesticide intermediate. Approximately 50% of the p-dichlorobenzene is used in the manufacture of space odorants and 40% is used in moth control. Pesticide manufacture, as a chemical intermediate, accounts for 10% of the p-dichlorobenzene usage.

Specific identified source locations of monochlorobenzene users are shown in Table 7-5.[7] They include nitrochlorobenzene, DDT, and diphenyl oxide producers. Monchlorobenzene usage was distributed based on the individual plant's production capacity. In the case of diphenyloxide, capacity numbers were not available so the usage was distributed evenly between both sites.

Specific identified source locations of o-dichlorobenzene users are shown in Tables 7-6 and 7-7. They include TDI production sites where o-dichlorobenzene is used as a solvent (Table 7-6[7]) and dichloroaniline sites where it is used as an intermediate (Table 7-7[7]). Total o-dichlorobenzene usage was distributed over the TDI sites based on TDI site capacity.

o-Dichlorobenzene usage for dichloroaniline manufacture was divided evenly over the four sites in the absence of capacity figures.

All other uses of chlorobenzenes are presented by a geographic region distribution in the emissions Section II of this report.

II. EMISSION ESTIMATES

A. PRODUCTION

Table 7-8 shows the monochlorobenzene emissions from production sites. Total estimated emissions from the 6 sites were 1,136,000 lb in 1978. Emission factors used to develop process, storage, and fugitive emission estimates are shown in Table 7-8. Process vent emissions originate primarily from distillation processes. Storage emissions represent losses from both working and final product storage tanks as well as loading and unloading losses. The number of tanks at a facility

Table 7-5. Monochlorobenzene End-Users[a]

Company	Location	End-Use Capacity (million lb/yr)	Monochloro-benzene Used (million lb/yr)	Geographic Coordinates Latitude/Longitude
		Nitrochlorobenzene Producers		
Du Pont	Deepwater, NJ	45	34	39 41 25/75 30 35
Monsanto	Sauget, IL	90	73	38 35 31/90 10 11
Total		140	107	
		DDT Producer		
Montrose	Torrance, CA	60	25	33 46 58/118 22 06
		Diphenyl Oxide Producers		
Dow	Midland, MI	NA[b]	14	43 35 28/84 13 08
Monsanto	Chocolate Bayou, TX	NA	14	29 14 55/95 12 45
Total			28	

[a] See ref. 7.

[b] Not available.

Table 7-6. o-Dichlorobenzene Solvent Users[a]
[Manufacturers of Toluene Diisocyanate (TDI)]

Company	Location	1978 TDI Capacity (10^6 lb/yr)	1978 o-Dichlorobenzene Use[b] (lb/yr)	Geographic Location Latitude/Longitude
Allied Chemical	Moundsville, WV	80	894,410	39 54 39/80 44 49
BASF Wyandotte	Geismar. LA	100	1,118,010	30 11 34/91 00 42
Dow Chemical	Freeport, TX	100	1,118,010	28 59 12/95 24 05
Du Pont	Deepwater, NJ	70	782,610	39 41 25/75 30 35
Mobay Chem. Corp.	Baytown, TX	130	1,453,416	29 45 30/94 54 25
	New Martinsville, WV	100	1,118,010	39 44 50/80 50 50
Olin Corp.	Ashtabula, OH	30	335,405	41 53 07/80 45 50
	Lake Charles, LA	100	1,118,010	30 13 55/93 15 57
Rubicon Chems. Inc.	Geismar, LA	40	447,205	30 12 00/91 11 30
Union Carbide	S. Charleston, WV	55	614,905	38 19 35/81 40 29
Total		805	9,000,000	

[a] See ref. 7.

[b] Total o-dichlorobenzene use is distributed per site based on TDI capacity.

Table 7-7. o-Dichlorobenzene Chemical Intermediate User Locations[*]

Source	Location	Geographic Coordinates (latitude/longitude)
2,4-Dichloroaniline		
Eastman Kodak Company	Rochester, NY	43 12 01/77 37 58
2,4-Dichloroaniline		
Blue Spruce Company	Bound Brook, NJ	40 32 10/74 29 18
Du Pont	Deepwater, NY	39 41 25/75 30 35
Monsanto	Luling, LA	29 55 10/90 22 30

[*] See ref. 7.

Table 7-8. Monochlorobenzene Emissions from Production Sites

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Dow	Midland, MI	208,060	45,450	69,690	323,200	4.65
ICC	Niagara Falls, NY	10,300	2,250	3,450	16,000	0.23
Monsanto	Sauget, IL	142,140	31,050	47,610	220,800	3.18
Montrose	Henderson, NV	65,920	14,400	22,080	102,400	1.47
PPG	New Martinsville, WV	162,740	35,550	54,510	252,800	3.64
Standard Chlorine	Delaware City, DE	142,140	31,050	47,610	220,800	3.18
Total		731,300	159,750	244,950	1,136,000	

[a] Based on the following emission factors (lb emitted per lb produced). See ref. 8.

Process 0.00206 A - (derived from site visit data)
Storage 0.00045 A - (derived from site visit data)
Fugitive 0.00069 A - (derived from site visit data)
Total 0.00320

[b] Based on 8760 hr/yr operation.

are a function of the production and tank sizes. Fugitive emissions are those that result from plant equipment leaks. Emission estimates are based on a plant operation schedule of 24 hr/day, 7 days/week, 52 weeks/yr.

Table 7-9 shows the o-dichlorobenzene emissions from production sites. Total estimated emissions from the 7 sites were 209,450 lb in 1978. Emission factors used to develop the process, storage, and fugitive emissions are shown in Table 9.

Table 7-10 shows the p-dichlorobenzene emissions from production sites. Total estimated emissions from the 8 sites were 398,200 lb in 1978. Emission factors used to develop the process, storage, and fugitive emissions are shown in Table 7-10.

B. USES

1. Monochlorobenzene

It was estimated that 75% of the chlorobenzene used as solvent was consumed in cold cleaning operations. Total emissions of 130,500,000 lb were derived by assuming that all chlorobenzene consumed was lost. The total number of cleaners in service and the average emission rate per unit are shown in Table 7-11. Distribution of the cold cleaners by geographic region is shown in Table 7-12.

The remaining chlorobenzene was used as a solvent in pesticide manufacture. The entire amount used (43,500,000 lb) was assumed to be lost. The total emissions that are shown in Table 7-13 by geographic region were distributed by the number of sites in each region.

Emissions from chlorobenzenes used as chemical intermediates are summarized in Table 7-14. They were derived from the emission factors shown in Table 7-15. Emissions from nitrochlorobenzene, DDT, and diphenyl oxide were estimated to be 171,200 lb, 12,500 lb, and 28,500 lb respectively.

Miscellaneous uses of chlorobenzene were estimated by using an average emission factor derived for all other chlorobenzene uses of 0.00133 lb lost/lb used times the usage. Emissions from miscellaneous uses were estimated to have been 27,930 lb. Source locations could not be identified for regional distribution.

Table 7-9. o-Dichlorobenzene Emissions from Production Sites

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Dow	Midland, MI	27,840	5,640	9,120	42,600	0.61
Monsanto	Sauget, IL	13,920	2,820	4,560	21,300	0.31
PPG	New Martinsville, WV	34,800	7,050	11,400	53,250	0.77
Standard Chlorine	Delaware City, DE	44,080	8,930	14,440	67,450	0.97
Specialty Organics	Irwindale, CA	2,320	470	760	3,550	0.05
Montrose	Henderson, NV	6,960	1,410	2,280	10,650	0.15
ICC	Niagara Falls, NY	6,960	1,410	2,280	10,650	0.15
Total		136,880	27,730	44,840	209,450	

[a] Based on the following emission factors (lb emitted per lb produced). See ref. 8.

Process 0.00232 A - (derived from site visit data)
Storage 0.00047 A - (derived from site visit data)
Fugitive 0.00076 A - (derived from site visit data)
Total 0.00355

[b] Based on 8760 hr/yr operation.

Table 7-10. p-Dichlorobenzene Emissions from Production Sites

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Dow	Midland, MI	52,290	3,690	9,180	65,160	0.94
Monsanto	Sauget, IL	23,240	1,640	4,080	28,960	0.42
PPG	New Martinsville, WV	75,530	5,330	13,260	94,120	1.35
Standard Chlorine	Delaware City, DE	139,440	9,840	24,480	173,760	2.50
Specialty Organics	Irwindale, CA	5,810	410	1,020	7,240	0.10
Montrose	Henderson, NV	11,620	820	2,040	14,480	0.21
ICC	Niagara Falls, NY	11,620	820	2,040	14,480	0.21
Total		319,550	22,550	56,100	398,200	

[a] Based on the following emission factors (lb emitted per lb produced). See ref. 8.

Process 0.00581 A - (derived from site visit data)
Storage 0.00041 A - (derived from site visit data)
Fugitive 0.00102 A - (derived from site visit data)
Total 0.00724

[b] Based on 8760 hr/yr operation.

Table 7-11. Chlorobenzene Emissions from Solvent Degreasers[a]

Type Degreaser	Estimated National Emission (M lb/yr)[b]	Estimated Number of Units in Service	Average Emission Rate per Unit (lb/yr)	Average Emission Rate per Unit (g/sec)[c]
Cold cleaners	130.5	197,428	661	0.04

[a] See refs. 3 and 9.

[b] Assumes all chlorobenzene used in cold cleaners is lost.

[c] Based on 2250 hr/yr operation.

Table 7-12. Estimated Number of Degreasers Using Chlorobenzene in 1978 by Geographic Location*

Degreaser Type	North East	Mid Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
Cold cleaners	11,869	30,780	52,272	17,309	23,817	11,678	19,166	7,164	23,374	197,428

*See ref. 10.

Table 7-13. 1978 Chlorobenzene Emission Estimates from Pesticide Manufacturers[a]

Region	Number of Sites per Region	Monochlorobenzene Emissions as Solvent (lb/yr)[b]	o-Dichlorobenzene Emissions (lb/yr)[c]	p-Dichlorobenzene Emissions (lb/yr)[d]
New England	4	1,251,800	43	80
Middle Atlantic	37	11,579,135	400	730
East North Central	19	5,946,045	205	375
West North Central	15	4,694,245	160	295
South Atlantic	17	5,320,145	185	335
East South Central	14	4,381,295	150	275
West South Central	15	4,694,245	160	295
Mountain	5	1,564,750	55	100
Pacific	13	4,068,345	140	255
Total	139	43,500,000	1500	2750

[a] See ref. 10.

[b] Average per site 312,950 lb/yr (4.51 g/sec).

[c] Average per site 10.8 lb/yr (0.0002 g/sec).

[d] Average per site 19.8 lb/yr (0.0003 g/sec).

Table 7-14. Emissions from Chlorobenzene End-Users (Chemical Intermediate)

Company	Location	Emissions[a]				
		Process (lb/yr)	Storage (lb/yr)	Fugitive (lb/yr)	Total	
					lb/yr	g/sec[b]
Monochlorobenzene						
Du Pont	Deepwater, NJ	37,400	6,800	10,200	54,400	0.78
Monsanto	Sauget, IL	80,300	14,600	21,900	116,800	1.68
Montrose	Torrance, CA	10,000	1,250	1,250	12,500	0.18
Dow	Midland, MI	9,800	1,400	2,800	14,000	0.20
Monsanto	Chocolate Bayou, TX	9,800	1,400	2,800	14,000	0.20
o-Dichlorobenzene						
Eastman	Rochester, NY	9,975	1,425	2,850	14,250	0.21
Blue Spruce	Bound Brook, NJ	9,975	1,425	2,850	14,250	0.21
Du Pont	Deepwater, NY	9,975	1,425	2,850	14,250	0.21
Monsanto	Luling, LA	9,975	1,425	2,850	14,250	0.21

[a] Based on emission factors shown in table.

[b] Based on 8760 hr/yr operation.

Table 7-15. Chlorobenzenes End-User Emission Factors

End-User	Emission Factor (lb lost/lb used) Process	Storage	Fugitive	Total	Derivation[a]
Monochlorobenzene					
DDT	0.0004	0.00005	0.00005	0.00050	C[b]
Nitrochlorobenzene	0.0011	0.00020	0.00030	0.00160	C[b]
Diphenyloxide	0.0007	0.00010	0.00020	0.00100	B[c]
o-Dichlorobenzene					
4-Dichloroaniline	0.00105	0.00015	0.00030	0.00150	C[b]
Dye manufacturing	0.0004	0.00005	0.00005	0.0005	D
Pesticide intermed.	0.0004	0.00005	0.00005	0.0005	D
p-Dichlorobenzene					
Pesticide intermed.	0.0004	0.00005	0.00005	0.0005	D

[a] A - Basis: site visit data
B - Basis: state air files
C - Basis: published data
D - Basis: Hydroscience estimate

[b] See ref. 11.

[c] See ref. 12.

2. o-Dichlorobenzene

Emissions resulting from the use of o-dichlorobenzene as a solvent in TDI manufacture were estimated to be 9,000,000 lb by assuming that all usage is lost. Table 7-16 summarizes TDI o-dichlorobenzene emissions which were distributed based on TDI capacity.

Emissions from chemical intermediate use of o-dichlorobenzene are shown in Table 7-14 for dichloroaniline manufacture (57,000 lb). Total emissions were distributed evenly per site since capacity data were not available. Emission factors used to derive o-dichlorobenzene emissions are shown in Table 7-15.

Pesticide intermediate uses of o-dichlorobenzene were estimated to have been 1500 lb and were distributed by region in Table 7-13. Dye manufacturing losses were also estimated to be 1500 lb, but locations by region could not be identified.

Miscellaneous solvents primarily consumer types, (i.e., paint cleaners, engine cleaners, etc.) contributed 6,000,000 lb of o-dichlorobenzene emissions. Losses were considered too widespread to model.

p-Dichlorobenzene emissions from its use as a space deodorant were estimated as 27,500,000 lb and as 22,000,000 lb for moth control by assuming that total usage is lost. Losses were considered too widespread to model.

Emissions from p-dichlorobenzene used as a chemical intermediate in pesticide manufacture (2,750 lb) are shown in Table 13 by geographic region. Emissions were derived from the emission factors shown in Table 7-15 and distributed by the number of sites in each region.

Vent parameter data for producers and users of chlorobenzenes are shown in Table

Total emissions of all three chlorobenzenes are summarized in Table 7-18. Total nationwide emissions of chlorobenzene, o-dichlorobenzene, and p-dichlorobenzene were 175,376,130 lb, 15,269,240 lb, and 49,900,950 lb respectively in 1978. Total emissions of all chlorobenzenes were estimated to have been 240,546,530 lb.

Table 7-16. o-Dichlorobenzene Emissions from Solvent Use in TDI Production

Company	Location	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Allied Chemical	Moundsville, WV	894,410	12.88
BASF Wyandotte	Geismar, LA	1,118,010	16.10
Dow	Freeport, TX	1,118,010	16.10
Du Pont	Deepwater, NJ	782,610	11.27
Mobay	Baytown, TX	1,453,416	20.92
	New Martinsville, WV	1,118,010	16.10
Olin	Ashtabula, OH	335,405	4.83
	Lake Charles, LA	1,118,010	16.10
Rubicon	Geismar, LA	447,205	6.44
Union Carbide	S. Charleston, WV	614,905	8.85
Total		9,000,000	

[a] Based on total o-dichlorobenzene used as solvent lost as process emission.

[b] Based on 8760 hr/yr operation.

Table 7-17. Chlorobenzenes Vent Parameters[a]

		Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temp. (°F)	Velocity (ft/sec)	Distribution Area (ft x ft)
Production							
Process	m,o,p	3	60	0.125	104	20	
	p	5	30	0.80	120	12	
Storage	m	5	36	0.33	80		
	o	8	12	0.33	170		
	p	5	16	0.33	80		
Fugitive							300 x 600
Degreasing		1	15	0.5	70	0.6	
End-Uses[b]							
Process		1	20	0.17	140	12	
Storage		2	20	0.17	80		
Fugitive							100 x 100
Pesticide/DDT							
Process		1	30	0.17	100	15	
Storage		2	20	0.17	80		
Fugitive							300 x 300
TDI							
Process		1	90	0.9	110	40	

[a] Building cross-section

Production	- $50 m^2$
Degreasing	- $50 m^2$
End-uses	- $100 m^2$
Pesticide	- $100 m^2$
TDI	- $200 m^2$

[b] Includes dichloroaniline, nitro chlorobenzene, diphenyl oxide.

Table 7-18. 1978 Nationwide Emissions of Chlorobenzenes

Source	Nationwide Emissions (lb/yr)
Monochlorobenzene	
Production	1,136,000
Pesticide/degreasing solvents	174,000,000
Nitrochlorobenzene	171,200
DDT	12,500
Diphenyl oxide	28,500
Miscellaneous, other	27,930
Sub-total	175,376,130
o-Dichlorobenzene	
Production	209,450
3,4-Dichloroaniline	57,000
Toluene diisocynnate solvent	9,000,000
Miscellaneous solvents	6,000,000
Dye manufacturing	1,500
Pesticide intermediate	1,500
Sub-total	15,269,450
p-Dichlorobenzene	
Production	398,200
Space deodorant	27,500,000
Moth control	22,000,000
Pesticide intermediate	2,750
Sub-total	49,900,950
Total - all chlorobenzenes	240,546,530

[a] Based on an emission factor of 0.00133 lb lost/lb used derived from weighted average of all other monochlorobenzene uses.

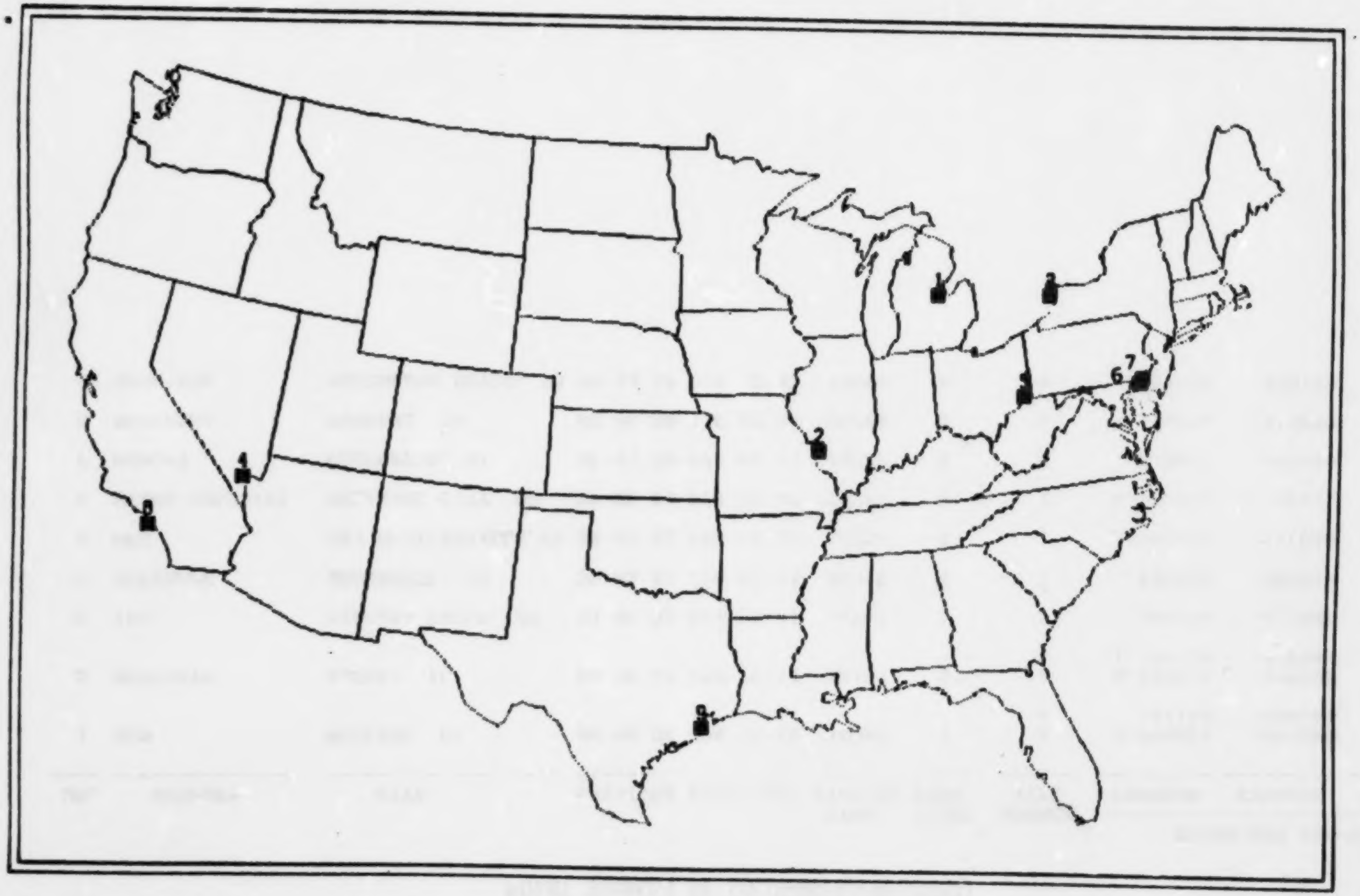

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FIGURE 7-1. SPECIFIC POINT SOURCES OF CHLOROBENZENE(MONO) EMISSIONS

TABLE 7-19. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF CHLOROBENZENE(MONO)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	DOW	MIDLAND, MI	43 38 28	084 13 08	14845	1	1 4	2.996064 .141120	.654480 .020160	1.008864 .040320
2	MONSANTO	SAUGET, IL	38 35 31	090 10 11	13994	2	1 2	2.046816 1.156320	.447120 .210240	.688584 .315360
3	ICC	NIAGARA FALLS, NY	43 03 33	079 00 55	14747	3	1	.146320	.032400	.049680
4	MONTROSE	HENDERSON, NV	36 03 32	114 58 34	23112	5	1	.949248	.207360	.317982
5	PPG	NEW MARTINSVILLE, WV	39 47 22	080 51 27	13736	3	1	2.343456	.511920	.784944
6	STAND CHLORINE	DELAWARE CITY, DE	39 33 54	075 38 47	94741	3	1	2.046816	.447120	.688584
7	DUPONT	DEEPWATER, NJ	39 41 25	075 30 35	13739	4	2	.538560	.097920	.144000
8	MONTROSE	TORRANC, CA	33 46 58	118 22 06	23129	5	3	.144000	.018000	.018000
9	MONSANTO	CHOCOLATE BAYOU, TX	29 14 55	095 12 45	12906	6	4	.141120	.020160	.040320

TABLE 7-19 (Concluded)

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* Plant Types:

Type 1: Plant produces chlorobenzene(mono) and diphenyl oxide

Type 2: Plant produces chlorobenzene(mono) and nitro chlorobenzene

Type 3: Plant produces chlorobenzene(mono)

Type 4: Plant produces nitro chlorobenzene

Type 5: Plant produces DDT

Type 6: Plant produces diphenyl oxide

† Source Types:

Type 1: Chlorobenzene(mono) production

Type 2: Nitro chlorobenzene production

Type 3: DDT production

Type 4: Diphenyl oxide production

TABLE 7-20. EXPOSURE AND DOSAGE OF CHLOROBENZENE(MONO) RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
100	12	1,450
50	48	3,910
25	228	10,010
10	1,808	33,200
5	5,627	58,500
2.5	12,867	83,600
1	53,490	142,000
0.5	155,559	212,000
0.25	353,475	282,000
0.1	841,655	356,000
0.05	1,421,298	397,000
0.025	1,909,743	415,000
0.000432*	4,065,898	430,000

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 7-21. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF CHLOROBENZENE (MONO)

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)			Dosage [$10^6(\mu g/m^3)\cdot$persons]		
	Degreasing Operation	Pesticide Production	U.S. Total	Degreasing Operation	Pesticide Production	U.S. Total
100	0	1.1	1.1	0	0.14	0.14
50	0	11	11	0	0.81	0.81
25	0	46	46	0	2.0	2.0
10	0	213	213	0	4.81	4.81
5	0	394	394	0	5.26	5.26
2.5	0	913	913	0	7.01	7.01
1.5	0	2,640	2,640	0	9.62	9.62
0.5	0	5,700	5,700	0	11.8	11.8
0.25	--	--	--	1.06	12.6	13.7
0.10	--	--	--	5.5	14.5	20.0
0.05	--	--	--	9.4	15.3	24.7
0.025	--	--	--	13.0	15.9	29.0
0.010	--	--	--	19.9	16.7	36.6
0	--	--	--	55.3	17.4	72.6

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 7-22. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF CHLOROBENZENE (MONO)

Parameter	Value
Daytime decay rate (K_d)	4.67×10^{-6} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	0.402 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 7-23. CHLOROBENZENE (MONO) EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.001000	505140	1001.9	0.	100.0	0.	100.0	0.	0.
.000500	9149730	8201.1	0.	100.0	0.	100.0	0.	0.
.000250	27019254	14972.1	0.	100.0	0.	100.0	0.	0.
.000100	95892357	25160.8	0.	100.0	0.	97.3	1.2	1.5
.000050	140093202	28469.2	0.	100.0	0.	94.2	2.5	3.3
0.	158679135	29091.4	0.	100.0	0.	92.9	2.6	4.5

TABLE 7-24. EXPOSURE AND DOSAGE SUMMARY OF CHLOROBENZENE(MONO)

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
100	12	1,100	0	1,112	1,450	140,000	0	141,450
50	48	11,000	0	11,048	3,910	810,000	0	813,910
25	228	46,000	0	46,228	10,010	2,000,000	0	2,010,010
10	1,808	213,000	0	214,808	32,200	4,810,000	0	4,842,200
5	5,627	394,000	0	399,627	58,500	5,260,000	0	5,318,500
2.5	12,867	913,000	0	925,867	83,600	7,010,000	0	7,840,600
1	53,490	--	0		142,000		0	
0.5	155,559	5,700,000	0	5,855,559	212,000	11,800,000	0	12,012,000
0.25	353,475	--	0	--	282,000	13,700,000	0	13,982,000
0.1	841,655	--	0	--	356,000	20,000,000	0	20,356,000
0.05	1,421,298	--	0	--	397,000	24,700,000	0	25,097,000
0.025	1,909,743	--	0	--	415,000	29,000,000	0	29,415,000
0.01	--	--	0	--	430,000	36,600,000	0	--
0.001	--	--	505,140	--	--	--	1,082	--
0.0005	--	--	9,149,730	--	--	--	8,281	--
0.00025	--	--	27,819,254	--	--	--	14,972	--
0.0001	--	--	95,892,857	--	--	--	25,169	--
0.00005	--	--	140,098,202	--	--	--	28,469	--
0	4,065,898	--	158,679,135	--	430,000	72,600,000	29,100	73,059,100

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

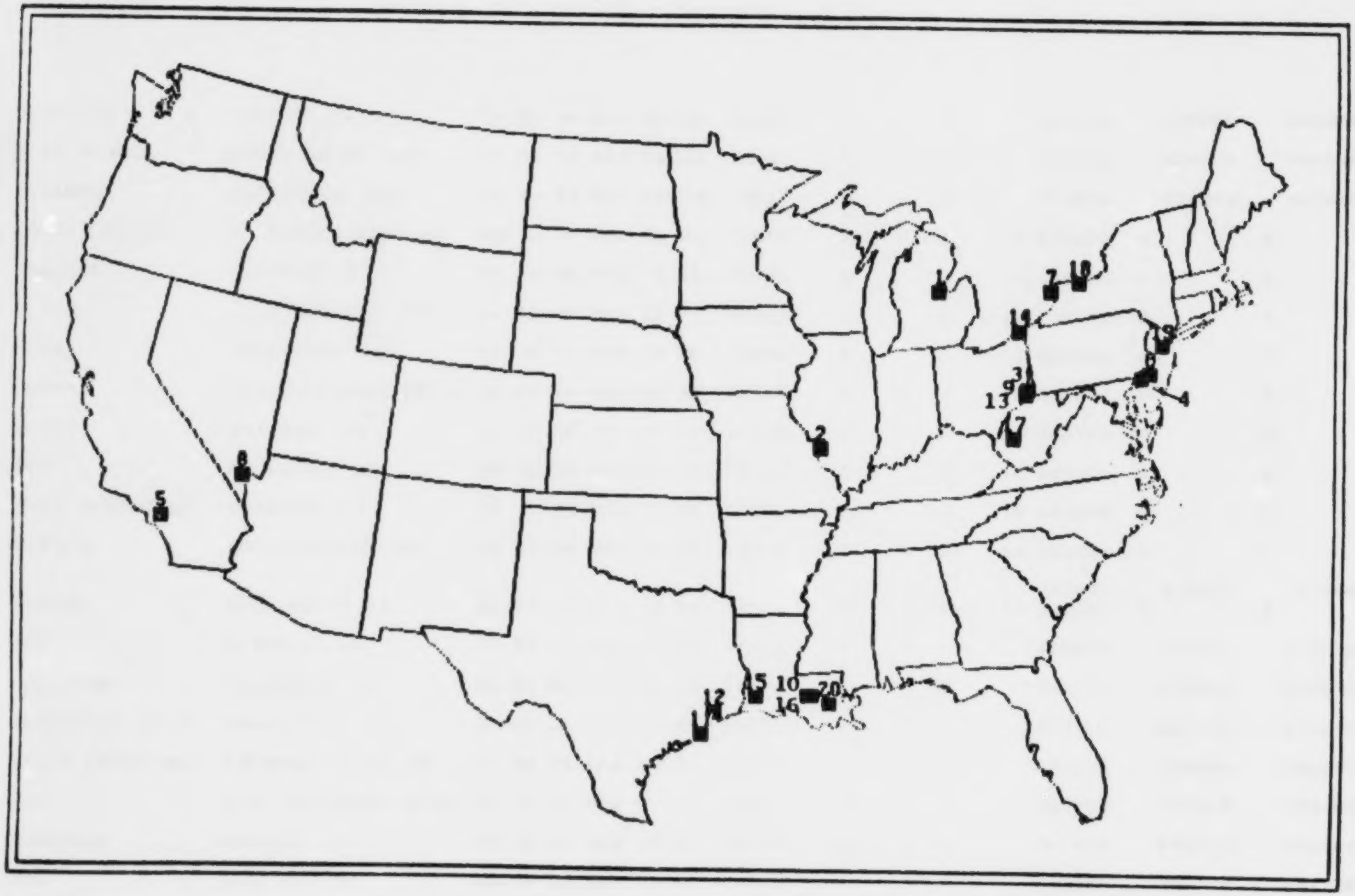

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FIGURE 7-2. SPECIFIC POINT SOURCES OF o-DICHLOROBENZENE EMISSIONS

TABLE 7-25. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF o-DICHLOROBENZENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	DOW	MIDLAND, MI	43 35 28	084 13 08	14845	1	1	.400896	.081216	.131328
2	MONSANTO	SAUGET, IL	38 35 31	090 10 11	13994	1	1	.200448	.040608	.065664
3	PPG	NEW MARTINSVILLE, WV	39 47 22	080 51 27	13736	1	1	.501120	.101520	.164160
4	STAND CHLORINE	DELAWARE CITY, DE	39 33 54	075 38 47	94741	1	1	.634752	.128592	.207936
5	SPECIALTY ORGAN	IRWINDALE, CA	34 06 30	117 55 48	23215	1	1	.033408	.006768	.010944
6	MONTROSE	HENDERSON, NV	36 03 32	114 58 34	23112	1	1	.100224	.020304	.032032
7	ICC	NIAGARA, NY	43 03 33	079 00 55	14747	1	1	.100224	.020304	.032832
8	DUPONT	DEEPWATER, NJ	39 41 25	075 15 50	13739	2	2 3	11.269584 .143640	0. .020520	0. .041040
9	ALLIED	MOUNDSVILLE, WV	39 54 39	080 44 49	13736	3	2	12.879504	0.	0.
10	BASF WYANDOTTE	GEISMAR, LA	30 11 34	091 00 42	13970	3	2	16.099344	0.	0.
11	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	3	2	16.099344	0.	0.
12	MOBAY	BAYTOWN, TX	29 45 30	094 54 25	12906	3	2	20.929190	0.	0.
13	MOBAY	NEW MARTINSVILLE, WV	39 44 30	080 50 50	13736	3	2	16.099344	0.	0.
14	OLIN	ASHTABULA, OH	41 53 07	080 45 50	14843	3	2	4.829832	0.	0.
15	OLIN	LAKE CHARLES, LA	30 13 55	093 15 57	03937	3	2	16.099344	0.	0.
16	RUBICON	GEISMAR, LA	30 12 00	091 11 30	12958	3	2	6.439782	0.	0.
17	UNION CARBIDE	S. CHARLESTON, WV	38 19 33	081 40 29	13866	3	2	8.854632	0.	0.
18	EASTMAN	ROCHESTER, NY	43 12 01	077 37 58	14771	4	3	.143640	.020520	.041040
19	BLUE SPRUCE	BOUND BROOK, NJ	40 32 10	074 29 18	14737	4	3	.143640	.020520	.041040
20	MONSANTO	LULING, LA	29 55 10	090 22 30	13958	4	3	.143640	.020520	.041040

TABLE 7-25 (Concluded)

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* Plant Types:

Type 1: Plant produces o-Dichlorobenzene
Type 2: Plant produces Toluene diisocyanate and 3,4-Dichloroaniline
Type 3: Plant produces Toluene diisocyanate
Type 4: Plant produces 3,4-Dichloroaniline

† Source Types:

Type 1: o-Dichlorobenzene production
Type 2: Toluene diisocyanate production
Type 3: 3,4-Dichloroaniline production

TABLE 7-26. EXPOSURE AND DOSAGE OF o-DICHLORO BENZENE FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
100	2	175
50	38	2,520
25	4,258	147,000
10	16,315	349,000
5	25,406	407,000
2.5	57,100	509,000
1	159,047	658,000
0.5	352,618	790,000
0.25	655,976	897,000
0.1	955,490	952,000
0.05	1,210,194	968,000
0.000198*	6,442,161	1,010,000

---

*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 7-27. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF o-DICHLOROBENZENE (PESTICIDE PRODUCTION)

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)	Dosage [$10^3(\mu g/m^3)\cdot$persons]
0.010	0.2	0.002
0.0050	4	0.03
0.0025	25	0.10
0.0010	--	0.23
0.00050	--	0.34
0.00025	--	0.47
0	--	2.02

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 7-28. **MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF o-DICHLOROBENZENE**

Parameter	Value
Daytime decay rate (K_d)	7.5×10^{-6} sec^{-1}
Nighttime decay rate (K_n)	5.0×10^{-7} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	86.42 gm/sec
Dye production	0.02 gm/sec
Miscellaneous solvents	86.4 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 7-29. o-DICHLOROBENZENE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.250000	505140	282451.4	0.	100.0	0.	100.0	0.	0.
.100000	9149780	1772052.3	0.	100.0	0.	100.0	0.	0.
.050000	38072205	3479775.2	0.	100.0	0.	100.0	0.	0.
.025000	81759648	5056481.0	0.	100.0	0.	98.0	.7	1.2
.010000	142928535	6121131.0	0.	100.0	0.	94.0	2.5	3.5
0.	158679135	6225594.7	0.	100.0	0.	92.9	2.6	4.5

TABLE 7-30. EXPOSURE AND DOSAGE SUMMARY OF o-DICHLOROBENZENE

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
100	2	0	0	2	175	0	0	175
50	38	0	0	38	2,520	0	0	2,520
25	4,258	0	0	4,258	147,000	0	0	147,000
10	16,315	0	0	16,315	349,000	0	0	349,000
5	25,406	0	0	26,406	407,000	0	0	407,000
2.5	57,100	0	0	57,100	509,000	0	0	509,000
1	159,047	0	0	159,047	658,000	0	0	658,000
0.5	352,618	0	0	352,618	790,000	0	0	790,000
0.25	655,976	0	505,140	1,161,116	897,000	0	232,451	1,129,451
0.1	955,490	0	9,149,730	10,105,220	952,000	0	1,772,052	2,724,052
0.05	1,210,194	0	33,072,205	34,282,399	968,000	0	3,479,775	4,447,775
0.025	--	0	81,759,648	--	--	0	5,056,481	--
0.01	--	2,000	142,928,535	--	--	2	6,121,131	--
0	6,442,161	--	158,679,135	--	1,010,000	2,020	6,225,594	7,238,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

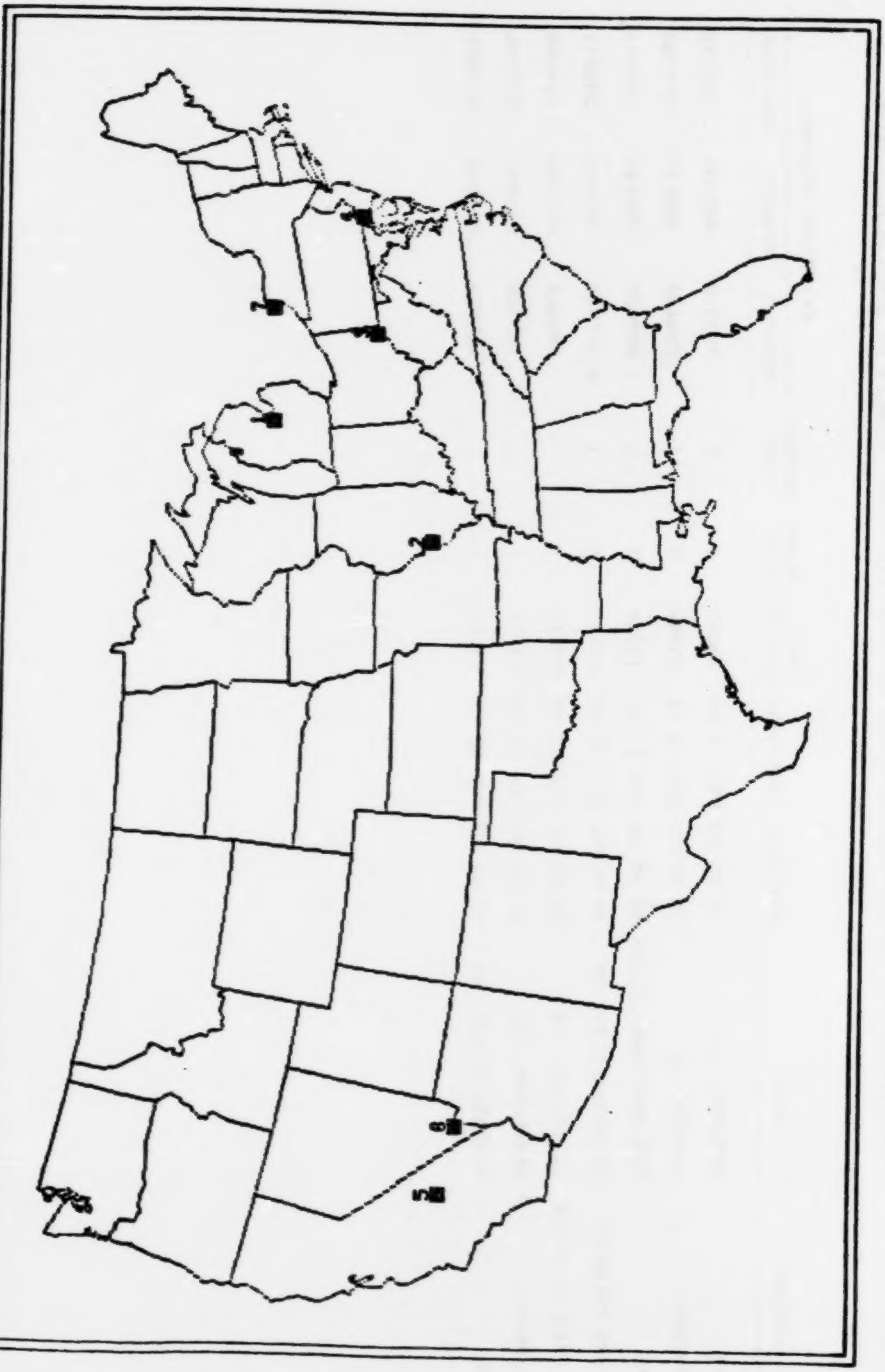


FIGURE 7-3. SPECIFIC POINT SOURCES OF p-DICHLOROBENZENE EMISSIONS

TABLE 7-31. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF p-DICHLOROBENZENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE	SOURCE TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	DOW	MIDLAND, MI	43 35 28	084 13 08	14845	1	1	.752976	.053136	.132192
2	MONSANTO	SAUGET, IL	38 35 31	090 10 11	13994	1	1	.334656	.023616	.058752
3	PPG	NEW MARTINSVILLE,WV	39 47 22	080 51 27	13736	1	1	1.087632	.076752	.190944
4	STAND CHLORINE	DELEWARE CITY, DE	39 33 54	075 38 47	94741	1	1	2.007936	.141696	.352512
5	SPECIALTY ORGAN	IRWINDALE, CA	36 06 30	117 55 48	23215	1	1	.083664	.005904	.014688
6	MONTROSE	HENDERSON, NV	36 03 32	114 58 34	23112	1	1	.167328	.011808	.029376
7	ICC	NIAGARA FALLS, NY	43 03 33	079 00 55	14747	1	1	.167328	.011808	.029376

TABLE 7-32. EXPOSURE AND DOSAGE OF p-DICHLOROBENZENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
100	2	239
50	8	662
25	30	1,360
10	125	2,780
5	342	4,380
2.5	1,233	7,360
1	3,747	11,300
0.5	9,714	15,000
0.25	18,980	18,900
0.1	94,145	29,500
0.05	259,561	40,400
0.025	552,574	51,200
0.01	1,151,587	60,600
0.005	1,663,080	64,300
0.000482	2,341,103	66,000

TABLE 7-33. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF p-DICHLOROBENZENE (PESTICIDE PRODUCTION)

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)	Dosage [$10^3(\mu g/m^3)\cdot$persons]
0.010	2	0.03
0.0050	21	0.15
0.0025	58	0.29
0.0010	--	0.54
0.00025	--	0.77
0	--	3.36

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 7-34. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF p-DICHLOROBENZENE

Parameter	Value
Daytime decay rate (K_d)	7.5×10^{-6} sec^{-1}
Nighttime decay rate (K_n)	5.0×10^{-7} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	713 gm/sec
Space deodorant	396 gm/sec
Moth control	317 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 7-35. p-DICHLOROBENZENE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
2.500000	506140	1917817.8	0.	100.0	0.	100.0	0.	0.
1.000000	9149730	14620149.2	0.	100.0	0.	100.0	0.	0.
.500000	26976292	26029918.4	0.	100.0	0.	100.0	0.	0.
.250000	61583693	37167988.3	0.	100.0	0.	100.0	0.	0.
.100000	133037356	49590816.2	0.	100.0	0.	90.3	.5	1.2
0.	150679135	51363670.0	0.	100.0	0.	94.7	2.4	2.9
			0.	100.0	0.	92.9	2.6	4.5

TABLE 7-36. EXPOSURE AND DOSAGE SUMMARY OF p-DICHLOROBENZENE

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [(g/m^3)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
100	2	0	0	2	239	0	0	239
50	8	0	0	8	662	0	0	662
25	30	0	0	30	1,360	0	0	1,360
10	125	0	0	125	2,780	0	0	2,780
5	342	0	0	342	4,380	0	0	4,380
2.5	1,233	0	505,140	505,373	7,360	0	1,917,818	1,925,178
1	3,747	0	9,149,730	9,153,477	11,300	0	14,620,149	14,631,449
0.5	9,714	0	26,976,292	26,986,006	15,000	0	26,029,918	26,044,918
0.25	18,980	0	61,583,693	61,682,673	18,900	0	37,167,988	37,186,888
0.1	94,145	2,000	133,037,356	133,639,503	29,500	30	49,590,816	49,620,346
0.05	259,561	21,000	--	--	40,400	150	--	--
0.025	552,574	--	--	--	51,200	--	--	--
0.01	1,151,587	--	--	--	62,600	--	--	--
0.005	1,663,080	--	--	--	64,300	--	--	--
0	2,341,103	--	158,679,135	--	66,000	3,360	51,363,678	51,430,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. "Chemical Product Synopsis on Monochlorobenzene," Mannsville Chemical Products, July 1977.

2. "Chemical Profile on Monochlorobenzene," Oct. 31, 1977, Chemical Marketing Reporter.

3. E. M. Klapproth, "Chlorobenzenes," p. 633.5030A—I, Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (July 1977).

4. "Chemical Product Synopsis on Dichlorobenzene," Mannsville Chemical Products, June 1978.

5. "Chemical Profile on o-Dichlorobenzene," Sept. 6, 1976, Chemical Marketing Reporter.

6. "Chemical Profile on p-Dichlorobenzene," Mar. 15, 1976, Chemical Marketing Reporter.

7. 1978 Directory of Chemical Producers, United States, Stanford Research Institute, Menlo Park, CA.

8. S. W. Dylewsi, Emissions Control Options for the Synthetic Organic Chemicals Manufacturing Industry, Chlorobenzenes Product Report, Hydroscience, Inc., Knoxville, TN, August 1978.

9. Control of Volatile Organic Emissions from Solvent Metal Cleaning, EPA-450/2-77-022 (OAQPS No. 1.2-079), Research Triangle Park, NC (November 1977).

10. Solvent Metal Cleaning, Background Information: Proposed Standards (draft), EPA, NSPS, ESED, Research Triangle Park, NC (November 1978).

11. Special Project Report, "Petrochemical Plant Sites," prepared for Industrial Pollution Control Division, Industrial Environmental Research Laboratory, Environmental Protection Agency, Cincinnati, OH, by Monsanto Research Corp., Dayton, OH (April 1976).

12. Monsanto Corp., Chocolate Bayou, TX, Diphenyl Oxide Process, Texas Air Control Board emission inventory questionnaire for 1975.

APPENDIX A-8 ----- Chloroform

CHLOROFORM CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 67-66-3

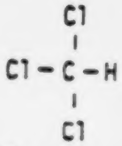
Synonyms: Trichloromethane; Methenyl Chloride; Trichloroform; Methenyl Trichloride; Formyl Trichloride; Methyl Trichloride

Chemical Formula

Molecular Weight: 119.39

Molecular Formula: $CHCl_3$

Molecular Structure:



$$\begin{array}{ccccc} & & Cl & & \\ & & | & & \\ Cl & - & C & - & H \\ & & | & & \\ & & Cl & & \end{array}$$

Chemical and Physical Properties

Physical State at STP: Liquid - highly refractive, nonflammable, heavy, very volatile

Boiling Point: 61.25°C

Melting Point: -63.5°C

Density: 1.49845 at 15°C

Vapor Pressure: 200 mm at 25.9°C

Vapor Density: 4.12

Solubility: Soluble (8.15 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 1.17

Atmospheric Reactivity

Transformation Products: Easily hydrolyzed by aqueous alkali to formic acid. When exposed to air and light, breaks down to phosgene, HCl, and chlorine.
Reactivity Toward OH·: same as methane, 1/4% Butane

Reactivity Toward O_3: No reaction

Reactivity Toward Photolysis: No photochemical degradation

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

Four volatile organic compounds——methyl chloride, methylene chloride, chloroform, and carbon tetrachloride——comprise the group of chemicals commonly referred to as the chloromethanes. Emission losses for all except methyl chloride are assessed in this summary.

CHLOROFORM

Chloroform ($CHCl_3$) is a clear, water-white, heavy, volatile, nonflammable liquid at ambient conditions and is manufactured by the chlorination of either methyl chloride or methane. The chlorination of methane is the predominant route for the manufacture of chloroform.

In 1978 five companies were operating plants at seven locations in the U.S. The locations of the plants, the type of production process used, and the 1978 capacity and estimated production level for each plant are shown in Table 8-1.[4,6,7] An estimated 330 million lb of chloroform was produced in 1978.

The largest end-use for chloroform is in the manufacture of chlorodifluoromethane, commonly referred to as fluorocarbon 22 or F-22. Fluorocarbon 22 is used primarily as a refrigerant with an estimated 61% of the chloroform production (201.3 million lb) consumed for this application. In addition an estimated 82.5 million lb of chloroform was consumed to produce fluorocarbon 22 that was subsequently used as a chemical intermediate to produce fluorocarbon resins.

The remaining 1978 chloroform production was either exported (23.1 million lb) or used as an industrial solvent to produce pharmaceuticals or pesticides (23.1 million lb). End-uses of chloroform are summarized in Table 8-2.[6]

For the purpose of this report emissions resulting from the export of chloroform are assumed to be negligible. The remaining chloroform produced (23.1 million lb) is used as a solvent in a variety of end-use applications and is eventually released to the atmosphere. Individual source locations could not be identified for this broad category. Estimated emissions losses for each producing location are shown in Table 8-3.

Total nationwide emissions of chloroform in 1978 from all sources are estimated to have been 24,040,000 lb. A tabulation of the losses is shown in Table 8-4.

The most significant end-use for chloroform is as a chemical intermediate in the production of fluorocarbon 22. Identified source locations for fluorocarbon 22 manufacture are shown in Table 8-5.[13] Also shown in that table are the 1973 fluorocarbon 22 production and the corresponding chloroform requirement for its manufacture.

Emission estimates of chlorofrom from these sites are shown in Table 8-6.[14] Total estimated emissions of chloroform from fluorocarbon 22 production sites are estimated to have been 587,000 lb in 1978. Additional associated emissions from these sites would include other halocarbons used and the various fluorocarbons produced. Vent parameter data relative to chloroform emissions from fluorocarbon production are shown in Table 8-7. It is estimated that an average of five tanks per site contribute chloroform storage emissions. Process emissions were reported as negligible.[14]

Table 8-1. Production of Chloroform[a]

Source	Location	1978 Estimated Production[b] (10^6 lb/yr)	Process[c]	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Allied Chemical Corp.	Moundsville, WV	19	A,B[d]	30	39 54 24/80 47 51
Diamond Shamrock	Belle, WV	26	A	40	38 14 09/81 32 38
Dow Chemical	Freeport, TX	64	B	100	28 59 15/45 24 45
	Plaquemine, LA	64	A	100	30 19 00/91 15 00
Stauffer Chemical Co.	Louisville, KY	49	A	75	38 12 09/85 51 49
Vulcan Materials Co.	Geismar, LA	38	A	60	30 10 00/90 59 00
	Wichita, KS	70	A,B[e]	110	37 36 55/97 18 30
Total		330		515	

[a] See refs. 4, 6, and 7.

[b] Distribution of the 330 million pounds per year for each producing location has been made as a direct ratio of total production/total capacity X individual plant capacity.

[c] (A) - Methanol hydrochlorination process or methyl chloride chlorination process.
(B) - Methane chlorination process.

[d] 5% methane chlorination 95% methyl chloride chlorination.

[e] 10% methane chlorination 90 % methyl chloride chlorination.

Table 8-2. 1978 Chloroform Consumption by End Use*

End Use	Percent of Total Consumption	End Use Consumption (M lb)
Chlorodifluoromethane (F-22) refrigerants	61	201.3
Chlorodifluoromethane (F-22) resin intermediates	25	82.5
Export	7	23.1
Solvent/miscellaneous	7	23.1
Total	100	330.0

*See refs. 6 and 7.

Table 8-3. 1978 Chloroform Production Emissions

		Process Vent Emissions		Storage Vent Emissions		Fugitive Emissions		Total Emissions[a]	
Company	Location	(lb/yr)	(g/sec)[b]	(lb/yr)	(g/sec)[b]	(lb/yr)	(g/sec)[b]	(lb/yr)	(g/sec)[b]
Allied Chemical	Moundsville, WV	140	0.002	17,870	0.257	4,630	0.067	22,640	0.326
Diamond Shamrock	Belle, WV	200	0.003	25,350	0.365	6,420	0.092	31,970	0.460
Dow Chemical	Freeport, TX	260	0.004	18,470	0.266	11,500	0.166	30,230	0.435
	Plaquemine, LA	480	0.007	62,400	0.898	15,810	0.228	78,690	1.133
Stauffer	Louisville, KY	370	0.005	47,780	0.688	12,100	0.174	60,250	0.867
Vulcan	Geismar, LA	290	0.004	37,050	0.533	9,390	0.135	46,730	0.673
	Wichita, KA	500	0.007	63,450	0.913	16,820	0.242	80,770	1.163
Total		2,240		272,370		76,670		351,280	

[a] Derived from the emission factors shown in Table 10.

[b] Based on 8760 hr/yr operation.

Table 8-4. 1978 Estimated Chloroform Nationwide Emission Losses

Source	Estimated National Emission ($\bar{M}$ lb/yr)
Production	0.35
Chlorodifluoromethane (F-22) (refrigerants)	0.59
Chlorodifluoromethane (F-22) resin intermediates	
Solvent, miscellaneous	23.1
Export	0
Total	24.04

Table 8-5. Users of Carbon Tetrachloride and Chloroform to Produce Fluorocarbons

	Flurorocarbon Annual Capacity (10^6 lb)	Estimated 1978 Production			Estimated Production Totals (10^6 lb)	Carbon Tetrachloride Used (10^6 lb)	Chloroform Used (10^6 lb)	Geographic Coordinates Latitude/Longitude
		F-11 (10^6 lb)	F-12 (10^6 lb)	F-22 (10^6 lb)				
Allied Chemical								
Baton Rouge, LA	310	Assumed shut down						
Danville, IL		28.5	40.6		282.9	87.3		40 08 30/87 33 45
Elizabeth, NJ		28.5	40.6	37.8		87.3	55.7	40 40 45/74 13 51
El Segundo, CA		28.5	40.6	37.8		87.3	55.7	33 56 30/118 26 35
Du Pont								
Antioch, CA	400	36.8	52.3		364.9	112.6		37 59 37/121 52 00
Deepwater, NJ		36.8	52.3	48.8		112.6	71.9	39 41 25/75 30 35
Montague, MI		36.8	52.3			112.6		43 24 10/86 23 40
Louisville, KY				48.8			71.9	38 11 51/85 54 13
Corpus Christi, TX								27 53 00/97 15 00
Pennwalt Corp.								
Calvert City, KY	80	22.1	31.4	19.5	73.0	67.6	28.6	37 03 18/88 19 40
Thorofare, NJ	35	Assumed shutdown						
Union Carbide								
Institute and S. Charleston, WV	Not listed	Assumed shutdown						
Essex Chemical Corp. (Racon)								
Wichita, KS	20							
Kaiser Aluminum & Chemical Corp.								
Gramercy, LA	80							
Total	925	218	310.1	192.7	720.8	667.5	283.8	

*See ref. 13.

Table 8-6. Emissions from Carbon Tetrachloride and Chloroform Users for Flurocarbon Production[a]

		F-11/F-12 Carbon Tetrachloride Emissions		F-22 Chloroform Emissions	
Source	Location	(lb/yr)[b]	(g/sec)[d]	(lb/yr)[c]	(g/sec)[d]
Allied	Danville, IL	58,460	0.84	0	
	Elizabeth, NJ	58,460	0.84	115,200	1.66
	El Segundo, CA	58,460	0.84	115,200	1.66
Du Pont	Antioch, CA	75,420	1.09	0	0
	Deepwater, NJ	75,420	1.09	148,800	2.14
	Montague, MI	75,420	1.09	0	0
	Louisville, KY	0		148,800	2.14
Pennwalt	Calvert City, KY	45,240	0.65	59,410	0.86
Total		446,200		587,410	

[a] See ref. 14.

[b] Based on the following emission factor:

Process	0.000449	A - (derived from site visit)
Storage	0.000442	A - (derived from site visit)
Fugitive	0.000178	A - (derived from site visit)
	0.001069	

[c] Based on the following emission factor:

Process	0	A - (derived from site visit)
Storage	0.00374	A - (derived from site visit)
Fugitive	0.00075	A - (derived from site visit)
	0.00449	

[d] Assumes 8760 hours/year operation.

Table 8-7. **Chloromethane Vent Parameters**[a]

Source	Number of Vents	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
ion[b]					
l chloride chlo- ation					
Process	3	35	0.08	95	5.0
Storage	10	20	0.17	80	
ne chlorination					
Process	2	35	0.08	100	270
Storage	10	20	0.17	80	
disulfide and er chlorination cesses					
Process	2	45	0.17	100	9.0
Storage	7	20	0.17	80	
ene chloride end-use[c]					
Cold cleaner	1	15	0.5	70	0.6
Vapor degreaser	1	15	0.5	150	
arbons 11/12[d]					
Process	2	30	0.33	90	
Storage	4	20	0.17	80	
arbon 22[d]					
Process[e]	0	0	0	0	0
Storage	2	20	0.17	80	

efs. 1, 2, 10, and 14.

ng cross-section - 5 m^2

ng cross-section - 50 m^2

ng cross-section - 20 m^2

are no process vent losses of chloroform from f-22 manufacture.

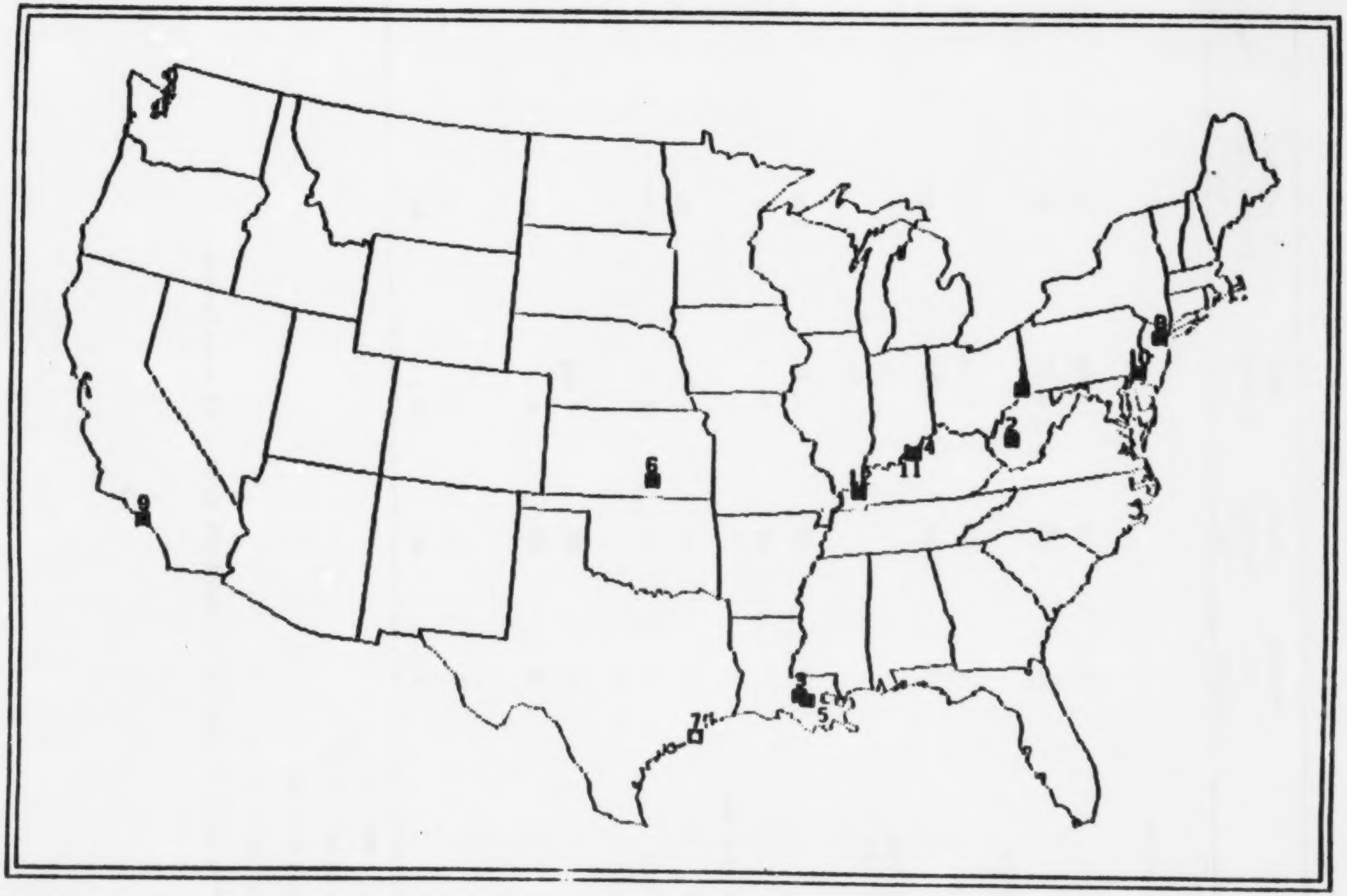

9
6
1
4
11
2
10
8
3
5
7

FIGURE 8-1. SPECIFIC POINT SOURCES OF CHLOROFORM EMISSIONS

TABLE 8-8. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF CHLOROFORM

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	ALLIED CHEMICAL	MOUNDSVILLE, WV	39 54 39	080 44 49	13736	1	1	.002016	.257328	.066672
2	DIAMND SHAMROCK	BELLE, WV	38 14 09	081 32 38	13866	1	1	.002880	.365040	.092440
3	DOW	PLAQUEMINE, LA	30 19 00	091 15 00	13970	1	1	.006912	.890560	.227664
4	STAUFFER	LOUISVILLE, KY	38 12 09	085 51 49	93820	1	1	.005328	.680032	.174240
5	VULCAN	GEISMAR, LA	30 10 00	090 59 00	12958	1	1	.004176	.533520	.138216
6	VULCAN	WICHITA, KA	37 36 55	097 18 30	03928	1	1	.007200	.913680	.242208
7	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	2	2	.003744	.265960	.166600
8	ALLIED	ELIZABETH, NT	40 40 45	074 13 51	04739	3	2	0.	.661824	.277056
9	ALLIED	EL SEGUNDO, CA	33 56 30	118 26 35	23129	3	2	0.	1.381824	.277056
10	DUPONT	DEEPWATER, NJ	39 41 25	075 30 35	13739	3	2	0.	1.784736	.357984
11	DUPONT	LOUISVILLE, KY	38 1 51	085 54 13	13807	3	2	0.	1.784736	.357984
12	PENNWALT	CALVERT CITY, KY	37 03 10	088 19 40	03816	3	2	0.	.712800	.142560

TABLE 8-9. (Concluded)

---

* Plant Type:

Type 1: Plant produces chloroform by using the methylchloride chlorination process

Type 2: Plant produces chloroform by using the methan chlorination process

Type 3: Plant produces flurocarbon 22

† Source Type:

Type 1: Methyl chloride chlorination process

Type 2: Methane chlorination process

Type 3: Flurocarbon 22 production

TABLE 8-10. EXPOSURE AND DOSAGE OF CHLOROFORM RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
67.6	1	34.7
50	2	87.6
25	21	736
10	111	2,110
5	224	2,910
2.5	679	4,430
1	2,513	6,850
0.5	4,684	8,370
0.25	13,630	11,500
0.1	68,319	19,000
0.05	217,703	29,200
0.025	447,556	37,400
0.01	826,081	43,400
0.00719*	866,290	43,800

---

*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 8-11. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF CHLOROFORM

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	332.6 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 8-12. CHLOROFORM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
1.000000	808144	898925.3	0.	100.0	0.	100.0	0.	0.
.500000	9149780	6898977.5	0.	100.0	0.	100.0	0.	0.
.250000	21839860	11010193.3	0.	100.0	0.	100.0	0.	0.
.100000	78609357	19384869.4	0.	100.0	0.	98.1	.7	1.2
.050000	129499838	23321696.1	0.	100.0	0.	95.2	2.3	2.5
0.	150679138	24223708.2	0.	100.0	0.	92.9	2.6	4.5

TABLE 8-13. EXPOSURE AND DOSAGE SUMMARY OF CHLOROFORM

Concentration Level (μg/m³)	Population Exposed (persons)				Dosage [(μg/m³)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
50	2	0	0	2	88	0	0	88
25	21	0	0	21	736	0	0	736
10	111	0	0	111	2,110	0	0	2,110
5	224	0	0	224	2,910	0	0	2,910
2.5	679	0	0	679	4,430	0	0	4,430
1	2,513	0	505,140	507,653	6,850	0	895,925	902,775
0.5	4,684	0	9,149,730	--	8,370	0	6,895,977	6,904,347
0.25	13,630	0	21,839,303	--	11,500	0	11,010,193	11,021,693
0.1	68,319	0	78,609,557	--	19,000	0	19,384,869	19,403,869
0.05	217,703	0	129,499,835	--	29,200	0	23,221,696	23,250,896
0.025	447,556	0	--	--	37,400	0	--	--
0.01	826,081	0	--	--	43,400	0	--	--
0.005	--	0	--	--	--	0	--	--
0	866,290	0	158,679,135	--	43,800	0	24,223,708	24,267,508

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative) to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. F. D. Hobbs and C. W. Stuewe, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Chloromethanes, Methane Chlorination Process (on file at EPA, ESED, Research Triangle Park, NC (January 1979).

2. F. D. Hobbs and C. W. Stuewe, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Chloromethanes, Methanol Hydrochlorination and Methyl Chloride Chlorination Processes (on file at EPA, ESED, Research Triangle Park, NC (January 1979).

3. "Chemical Product Synopsis on Methylene Chloride," Mannsville Chemical Products (March 1978).

4. T. E. Killilea, "Chlorinated Methanes," Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (April 1979).

5. "Chemical Profile on Methylene Chloride," Chemical Marketing Reporter (September 20, 1976).

6. "Chemical Product Synopsis on Chloroform," Mannsville Chemical Products (June 1978).

7. "Chemical Profile on Chloroform," Chemical Marketing Reporter (September 27, 1976).

8. "Chemical Product Synopsis on Carbon Tetrachloride," Mannsville Chemical Products (June 1978).

9. "Chemical Profile on Carbon Tetrachloride," Chemical Marketing Reporter (April 10, 1978).

10. F. D. Hobbs and C. W. Stuewe, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Carbon Tetrachloride and Perchloroethylene, Hydrocarbon Chlorinolysis Process (on file at EPA, ESED, Research Triangle Park, NC (March 1979).

11. Control of Volatile Organic Emissions from Solvent Metal Cleaning, EPA-450/2-77-022 (OAQPS No. 1.2-079), Research Triangle Park, NC (November 1977).

12. Solvent Metal Cleaning, Background Information: Proposed Standards (draft) EPA, NSPS, ESED, Research Triangle Park, NC (November 1978).

13. Chemical Research Services, 1979 Directory of Chemical Producers, United States of America, Stanford Research Institute, Menlo Park, CA.

14. D. M. Pitts, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry—Product Report on Fluorocarbons, on file at EPA, ESED, Research Triangle Park, NC (February 1979).

APPENDIX A-9 ----- Chloroprene

CHLOROPRENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 126-99-8

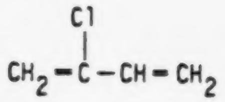
Synonyms: 2-Chlorobutadiene-1,3; β-Chloroprene; Chloroprene;
2-Chloro-1,3-Butadiene

Chemical Formula

Molecular Weight: 88.54

Molecular Formula: C_4H_5Cl,

Molecular Structure:



$$CH_2=\overset{\overset{Cl}{|}}{C}-CH=CH_2$$

Chemical and Physical Properties

Physical State at STP: Liquid-colorless, flammable, pungent ethereal odor

Boiling Point: 59.4°C at 760 mm

Melting Point:

Density: 0.9583 at 20°C/4°C

Vapor Pressure: 215.4 mm at 25°C

Vapor Density: 3.0

Solubility: Slightly soluble (<10.0 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products: 2-Chloroacrolein, Chloroacrolein

Reactivity Toward OH·: 4 x Butane

Reactivity Toward O_3: 2 x Propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors:

Formation Reactivity:

I. SOURCES

Chloroprene is currently produced in the United States by chlorination, isomerization, and caustic dehydrochlorination from butadiene. Until the late 1960s, chloroprene was also produced from acetylene, but that process has been discontinued because the cost of acetylene is much higher than that of butadiene.

Only two companies at three locations currently produce chloroprene in the United States. Dupont shut down its Louisville, KY, chloroprene facility and expanded its Laplace, LA, facility. Dupont's Victoria, TX, facility has also begun production of chloroprene. The locations of the plants and the 1978 capacity and estimated production for each site are shown in Table 9-1. An estimated 277.2 million lb of chloroprene was produced in 1978.[1,2]

All chloroprene produced is captively consumed to manufacture polychloroprene (neoprene) synthetic rubber by polymerization of the chloroprene. Neoprene is used in wire and cable covers, gaskets, automobile parts, caulks, and other applications requiring chemical, oil, and weather resistance.

II. EMISSION ESTIMATES

Emission estimates for the three sites listed in Table 9-1 include the total emissions of chloroprene, and toluene from the Dupont sites, for both the production of chloroprene and its captive use to make neoprene.

Emission factors used to calculate the emissions of chloroprene and toluene are shown in Table 9-2, along with vent parameter data.

Total emissions of chloroprene from its production and use are estimated to have been 3,523,090 lb, and those of toluene are estimated to have been 895,433 lb. There were no identified toluene emissions associated with chloroprene or neoprene manufacture at the Denka facility. Total emissions are shown in Table 9-3 by site location.

Table 9-1. Chloroprene Producers and Captive Users[a]

Company	Location	1978 Capacity (M lb)	1978 Production (M lb)[b]	Geographic Coordinates Latitude/Longitude
Du Pont	Laplace, LA	190	169.4	30 04 00/90 32 00
	Victoria, TX[c]	60	53.9	28 40 29/96 57 21
Denka	Houston, TX	60	53.9	29 41 31/95 15 12
Total		310	277.2	

[a] See refs. 1 and 2.

[b] Total production distributed over all sites based on capacity.

[c] Total capacity and estimated production have been determined by the difference in overall U.S. capacity and overall U.S. demand for neoprene.

Table 9-2. Chloroprene/Toluene Emission Factors and Vent Parameter Data

		Emission Factor lb Lost per lb Produced/Used			
Source	Chemical	Process	Storage	Fugitive	Total
		Emission Factors			
Du Pont sites	Chloroprene	0.014000[a]	0.000004[b]	0.001000[c]	0.015004
	Toluene	0.00347[a]	0.00004[a]	0.00050[c]	0.00401
Denka site	Chloroprene	0.002200[b]	0.000004[b]	0.001000[c]	0.003204

Vent Parameter Data

Source	Number of Vents	Vent Height (ft)	Vent Diameter (ft)	Vent Discharge Temperature (°F)	Vent Velocity (ft/sec)	Discharge Area (ft X ft)
All sites[d]						
Process	6	56	1.25	100	85	
Storage	4	16	0.33	75		
Fugitive						400 X 600

[a] See ref. 3.

[b] See ref. 4.

[c] Hydroscience estimate.

[d] Building cross section all sites - 100 m^2.

Table 9-3. Chloroprene and Toluene Emissions from Chloroprene Production and Use

		Emissions (lb/yr)[a]			Total Emissions[a]	
Company	Location	Process	Storage	Fugitive	(lb/yr)	(g/sec)
		Chloroprene Emissions				
Du Pont	Laplace, LA	2,371,600	678	169,400	2,541,678	36.59
	Victoria, TX	754,600	216	53,900	808,716	11.64
Denka	Houston, TX	118,580	216	53,900	172,696	2.49
Total		3,244,780	1,110	277,200	3,523,090	
		Toluene Emissions				
Du Pont	Laplace, LA	587,818	6,776	84,700	679,294	9.78
	Victoria, TX	187,033	2,156	26,950	216,139	3.11
Total		774,851	8,932	111,650	895,433	

[a] Based on emission factors shown in Table 2.

[b] Based on 8760 hr/yr operation.

Process emissions originate from the chloroprene reactor vent scrubber, the neoprene strippers, and the neoprene dryer exhausts. Storage emissions represent the losses from both working and final product storage as well as loading and handling losses. Fugitive emissions as those that result from plant equipment leaks.

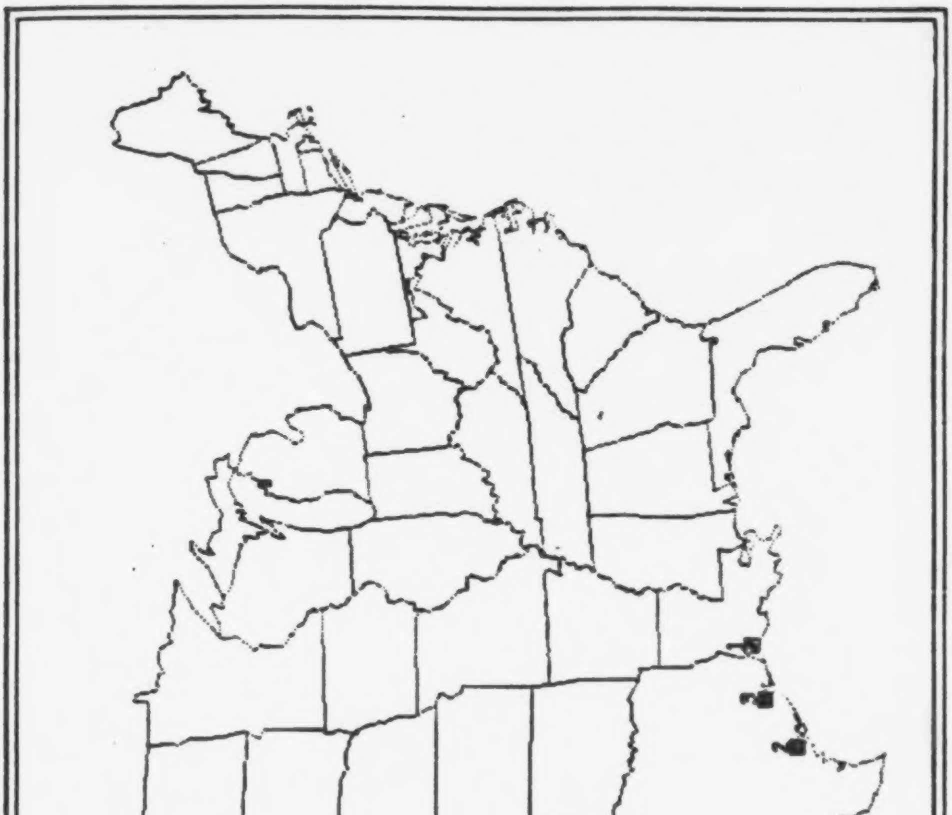


FIGURE 9-1: SPECIFIC POINT SOURCES OF CHLOROPRENE EMISSIONS

TABLE 9-4. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF CHLOROPRENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE	SOURCE TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	DUPONT	LAPLACE, LA	30 04 00	093 20 01	2958	1	1	34.151040	.009763	2.439360
2	DUPONT	VICTORIA, TX	28 40 29	096 57 21	12923	1	1	10.866240	.003110	.776160
3	DENKA	HOUSTON, TX	29 41 31	095 15 12	12906	1	1	1.707552	.003110	.776160

TABLE 9-5. EMISSIONS PARAMETERS FOR SPECIFIC POINT SOURCES OF CHLOROPRENE

Source Type	Emissions Category	Vent Height (m)	Building Cross Section (m^2)	Vent Diameter (m)	Vent Velocity (m/sec)	Vent Temperature (°k)
	Process	17	100	0.38	26	311
	Storage	5	100	--	--	--
	Fugitive	0	100	--	--	--

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 9-6. EXPOSURE AND DOSAGE OF CHLOROPRENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
96.6	1	75.4
50	55	3,340
25	292	11,000
10	2,038	34,200
5	5,170	54,600
2.5	9,136	60,300
1	29,573	100,000
0.5	48,326	121,000
0.25	92,173	126,000
0.1	227,457	146,000
0.05	454,997	162,000
0.025	989,679	181,000
0.01	1,369,545	188,000
0.005	1,411,458	188,000
0.00331*	1,414,691	188,000

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*The lowest annual average concentration occurring within 20 km of the specific point source.

REFERENCES

1. Sara L. Soder, "Butadiene Marketing Research Report," Chemical Economics Handbook, Stanford Research Institute, June 1977.

2. Chemical Marketing Reporter, Chemical Profiles Neoprene, August 16, 1976.

3. D. D. Wild, Louisiana Air Control Commission, Emission Inventory Questionnaire for Dupont Chemical, March 3, 1977.

4. M. Z. Woskow, Texas Air Control Board Emissions Inventory Questionnaire for Petrotex Chemical, Aug. 26, 1976.

APPENDIX A-10 ----- Cresol

m-CRESOL CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 108-39-4

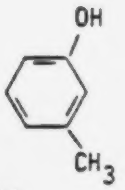
Synonyms: 3-Methylphenol; m- Hydroxyltoluene

Chemical Formula

Molecular Weight: 108.1

Molecular Formula: C_7H_8O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - colorless or yellowish, phenolic odor

Boiling Point: 202.8°C

Melting Point: 12°C

Density: 1.034 at 20°C/4°C

Vapor Pressure: 1 mm at 52.0°C

Vapor Density: 3.72

Solubility: Slightly soluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.37

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 12 x Butane

Reactivity Toward O_3: 10% Propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: Toluene

Formation Reactivity: Small formation pathway (<10% from all cresols) from toluene decay

o-CRESOL CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 95-48-7

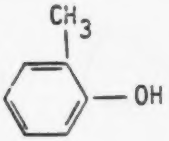
Synonyms: o-Cresylic Acid; o-Hydroxyltoluene; 2-Methylphenol

Chemical Formula

Molecular Weight: 108.1

Molecular Formula: C_7H_8O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Solid crystals - non volatile phenolic odor

Boiling Point: 190.8°C

Melting Point: 30.9°C

Density: 1.047 at 20°C/4°C

Vapor Pressure: 1 mm at 38.2°C

Vapor Density: 3.72

Solubility: Soluble (31 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 3.40

Atmospheric Reactivity

Transformation Products: Reacts with oxidizing materials to yield quinones and benzenes (<1 day in air, <10 days in water). Methyl quinone, methyldihydroxyl benzenes

Reactivity Toward OH·: 10 x Butane

Reactivity Toward O_3: 10% Propylene

Reactivity Toward Photolysis: N/A

Major Atmospheric Precursors: Toluene

Formation Reactivity: See m-Cresol

p-CRESOL CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 106-44-5

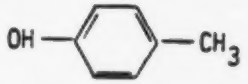
Synonyms: 4-Cresol; 4-Methylphenol; p-Hydroxyltoluene

Chemical Formula

Molecular Weight: 108.1

Molecular Formula: C_7H_8O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Solid crystals - phenolic odor

Boiling Point: 201.8°C

Melting Point: 35.26°C

Density: 1.0341 at 20°C/4°C

Vapor Pressure: 1 mm at 53.0°C

Vapor Density: 3.72

Solubility: Slightly soluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.35

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 10 x Butane

Reactivity Toward O_3: 10% Propylene

Reactivity Toward Photolysis:

Major Atmospheric Precursors: Toluene

Formation Reactivity: See m-Cresol

I. SOURCES

A. PRODUCTION

The cresol isomers include para-cresol, ortho-cresol, and meta-cresol. Production and capacity information is normally expressed in terms of total cresols and cresylic acid rather than the individual cresol isomers. Cresols typically occur as mixture of the cresol isomers and are defined as the compounds in the mixture with boiling points below 204°C. Cresylic acids are the compounds with boiling points above 204°C. Cresols and cresylic acid are produced as by-products of either coal tar distillation or petroleum naphtha cracking.

As a by-product of coal tar distillation, cresols and cresylic acids are obtained from the middle light oil cut of the distillation and from the filtrate remaining after crystallization of the naphthalene, which is also present in the middle light oil. Extraction of the filtrate with sodium hydroxide removes phenols, cresols, and xylenols. After separation in an aqueous layer, the phenols are acidifed to yield an organic layer which is then distilled to yield natural phenol, cresols, and xylenols. The crude cresol cut is further purified by fractional distillation to yield ortho-cresol and a mixture consisting of meta- and para-cresol. In the thermal cracking of naphtha and gas oil fractions, petroleum acids are obtained which can be processed by methods similar to the cresol recovery processes used by the coal tar distillation.[1]

p-Cresol is also produced synthetically by methylation of phenol.

There are currently six producers of mixed cresols. The locations of the plants and the 1978 capacity and estimated production level for each plant are shown in Table 10-1.[1] In 1978 an estimated 32 million lb of mixed cresols was produced. The average composition of the three isomers in the mixed cresols produced is estimated to have been 26% p-cresol, 31% o-cresol, and 43% m-cresol.[2,3]

There are also currently eight producers of cresylic acid. The locations of the plants and the 1978 capacity and estimated production of each are shown in Table 10-1. In 1978 an estimated 52 million lb of cresylic acid was produced. The average composition of the three isomers in the cresylic acid produced is estimated to

Table 10-1. Mixed Cresols and Cresylic Acid Producers[a]

Company	Location	Tar Acids Capacity (million lb/yr)	Cresols or Cresylic Acid Produced (million lb/yr)	Geographic Coordinates (Latitude/Longitude)
		Mixed Cresols Producers		
Continental Oil	Newark, NJ	50	6	40 43 34/74 07 26
Fallek	Tuscaloosa, AL	20	2	33 11 00/87 34 50
Ferro	Sante Fe Springs, CA	30	4	33 56 30/118 04 18
Koppers	Oil City, PA	35	4	41 29 30/79 43 20
Merichem	Houston, TX	100	12	29 45 36/95 10 48
Stimson	Anacartes, WA	30	4	48 28 31/122 32 48
Total		265	32	
		Cresylic Acid Producers		
Continental Oil	Newark, NJ	50	9	40 43 34/74 07 26
Crowley Tar Products	Houston, TX	30[b]	5	29 43 50/95 14 20
Fallek	Tuscaloosa, AL	20	3	33 11 00/87 34 50
Ferro	Sante Fe Springs, CA	30	5	33 56 30/118 04 18
Koppers	Follansbee, WV	35	6	40 23 10/80 35 07
Merichem	Houston, TX	100	17	29 45 36/95 10 48
Mobil Oil	Beaumont, TX	10	2	34 04 14/94 03 40
Stimson	Anacortes, WA	30	5	48 28 31/122 32 48
Total		305	52	

[a] See ref. 1.

[b] Hydroscience estimate.

have been 35% p-cresol, 3% o-cresol, and 34% m-cresol. The remaining 28% of cresylic acid is made up primarily of xylenols.[1]

Some of the cresols/cresylic acid manufacturers also produce individual isomers, with o- and m-cresols removed by extraction and distillation of the coal tars and petroleum fractions. p-Cresol isomer is produced synthetically.

There are currently six producers of o-cresol isomer in the United States. The locations of the plants and the 1978 capacity and production levels are shown in Table 10-2.[1] An estimated 30 million lb of o-cresol was produced in 1978.

Sherwin Williams at its Chicago, Illinois, plant produced an estimated 21 million lb of p-cresol synthetically in 1978. The plant location is shown in Table 10-2.

There were two m-cresol isomer producers in 1978 that manufactured an estimated 1.5 million lb. Source locations are shown in Table 10-2.[1]

A summary of the estimated cresol isomer composition of mixed cresols, cresylic acids, and a mixture of the two as used in 1978 is given in Table 10-3.[1,2,3]

B. USES

Table 10-4[1,4] shows the end-use distribution of the individual cresol isomers, the mixed cresols, and cresylic acid.

The manufactaure of 2,6-ditert butyl-p-cresol (BHT), which is used as a food preservative, consumed half of the o-cresol isomer production (15 million lb). Antioxidant manufacture consumed an estimated 10 million lb with the remainder being exported (5 million lb).

The majority of the p-cresol isomer produced was exported. Estimated exports in 1978 were 10.5 million lb, representing 50% of production. An estimated 5.5 million lb was consumed in phenolic resin manufacture, and 5.0 million lb was used to produce pesticides.

m-Cresol isomer production was used exclusively in the manufacture of pyrethroid pesticides (1.5 million lb).

Table 10-2. Cresol Isomer Producers[a]

Company	Location	Cresol Isomer Capacity (million lb/yr)	Cresol Isomer Produced (million lb/yr)	Geographic Coordinates (Latitude/Longitude)
		o-Cresol Producers		
Continental Oil	Newark, NJ	7.7	5.0	40 43 34/74 07 26
Fallek Chemical	Tuscaloosa, AL	9.6	6.0	33 11 00/87 34 50
Ferro Corp.	Sante Fe Springs, CA	4.5	3.0	33 56 30/118 04 18
Koppers	Oil City, PA	5.4	3.0	41 29 30/79 43 20
Merichem	Houston, TX	15.1	10.0	29 45 36/95 10 48
Stimson	Anacortes, WA	4.5	3.0	48 28 31/122 32 48
Total		46.8	30.0	
		p-Cresol Producer		
Sherwin Williams	Chicago, IL	NA[b]	21.0	41 43 04/87 36 30
		m-Cresol Producers		
Koppers	Oil City, PA	NA[b]	0.75	41 29 30/79 43 20
Merichem	Houston, TX	NA[b]	0.75	29 45 36/95 10 48
Total			1.50	

[a] See ref. 1.

[b] Not available.

Table 10-3. Cresol Isomer Compositions*

In mixed cresol 3 (both product and emissions)	
26%	p-cresol
31%	o-cresol
43%	m-cresol
100%	
In cresylic acid (both product and emissions)	
35%	p-cresol
3%	o-cresol
34%	m-cresol
28%	others, mainly xylenols
In mixed cresol/cresylic acid end-use (combined) and emissions	
31.6%	p-cresol
13.7%	o-cresol
37.4%	m-cresol
17.3%	others (mainly xylenols)

*See refs. 1, 2 and 3.

Table 10-4. 1978 End Use Distribution of Cresol Isomers, Cresols and Cresylic Acid*

End-Use	Isomer, Cresols, or Cresylic Acid Used (million lb/yr)	(%)
o-Cresol Isomer		
2,6-ditert butyl-p-cresol (BHT)	15.0	50
Antioxidants	10.0	33
Export	5.0	17
Total	30.0	100
p-Cresol Isomer		
Phenolic resins	5.5	26
Pesticides	5.0	24
Export	10.5	50
Total	21.0	100
m-Cresol Isomer		
Pyrethroid pesticides	1.5	100
Total	1.5	100
Mixed Cresols/Cresylic Acids (combined)		
Tricresyl phosphate (TCP) Cresyl diphenol phosphate (CDP)	31.0	32
Phenolic resins	20.0	21
Wire enamel solvent	20.0	21
Pesticides	8.0	8
Disinfectants/cleaning compound	3.0	3
Ore flotation	3.0	3
Miscellaneous other	7.0	7
Export	5.0	5
Total	97.0	100

*See refs. 1 and 4.

The only available data on the end-uses of mixed cresols and cresylic acid are in combined form. Total consumption of both mixed cresols and cresylic acid was 97 million lb with the difference between production (84 million lb) and use resulting from imports (13 million lb).

The largest end-use[5] of mixed cresols/cresylic acid was in tricresyl phosphate (plasticizer) manufacture (31 million lb), phenolic resins (20 million lb), and wire enamel solvent (20 million lb). Pesticide manufacture consumed 8 million lb; use in cleaning compounds and disinfectants for consumer use consumed 3 million lb; and use as an ore flotation agent consumed 3 million lb.

Other miscellaneous uses consumed 7 million lb, and exports accounted for 5 million lb.

Specific user locations for BHT producers, pyrethroid pesticide producers, and tricresyl phosphate producers are shown in Table 10-5.[5]

C. INCIDENTAL SOURCES

The major incidental source of cresol isomer emissions is coke ovens. Coal tars from coke ovens contain tar acids of 1.04% cresols.

Table 10-6[6] presents a list of coke oven plants in the U.S. Data to assign capacity and production to each site were not available. The total estimated coke production from these plants in 1978 was 107 billion lb.

II. EMISSION ESTIMATES

A. PRODUCTION

Emission factors used to develop production and end-use emission estimates for the isomers, mixed cresols, and cresylic acid are shown in Table 10-7.

Emissions from the production of mixed cresols and cresylic acid are shown in Table 10-8. Total cresol emissions from mixed cresol production were estimated to have been 80,000 lb in 1978. Of this total 24,800 lb were o-cresol, 20,800 lb were p-cresol, and 34,400 lb were m-cresol.

Table 10-5. Identified Source Locations of Cresols End-Users[a]

Company	Location	Production Capacity (lb/yr)	Cresol Usage (lb/yr)	Geographic Coordinates (Latitude/Longitude)
		o-Cresol Isomer		
2,6 di-tert-buty-p-cresol (BHT) Producers				
Ashland	Fords, NJ	12	5	40 31 20/74 20 50
Koppers	Oil City, PA	9	4	41 29 30/79 43 20
Shell	Martinez, CA	10	4	38 00 05/122 06 40
Uniroyal	Geismar, LA	5	2	30 13 30/91 00 15
Total		36	15	
		m-Cresol Isomer		
Pyrethroid Pesticide Producers				
CPC International	Lyndhurst, NJ	NA[b]	0.5	40 47 30/74 04 34
FMC	Baltimore, MD	NA	0.5	39 14 50/76 35 30
Vertac	West Helena, AR	NA	0.5	34 36 10/90 33 45
Total			1.5	
		Mixed Cresols/Cresylic Acid		
Tricresyl Phosphate/Cresyl Diphenyphosphate Producers				
FMC	Nitro, WV	60	20	38 25 33/81 50 05
Stauffer	Gallipolis Ferry, WV	35	11	38 46 40/82 10 54
Total		95	31	

[a] See ref. 5.

[b] Not available.

Table 10-6. Coke-Oven Plants in the United States*

Company	Location
Alabama By-Products Corporation	Tarrant, Alabama
Alan Wood Steel Company	Swedeland, Pennsylvania
Allied Chemical Corporation	
Semet-Solvay Division	Ashland, Kentucky Detroit, Michigan
Armco Steel Corporation	Hamilton, Ohio Houston, Texas Middletown, Ohio
Bethlehem Steel Corporation	Bethlehem, Pennsylvania Burns Harbor, Indiana Johnstown, Pennsylvania Lackawana, New York Sparrows Point, Maryland
Chattanooga Coke & Chemical Co. Inc.	Alton Park, Tennessee
Citizens Gas & Coke Utility	Indianapolis, Indiana
Colorado Fuel & Iron Steel Corporation	Pueblo, Colorado
Colt Industries Inc.	
Crucible Stainless Steel and Alloy Division	Midland, Pennsylvania
Cyclops Corporation	
Empire-Detroit Steel Division	Portsmouth, Ohio
Donner-Hanna Coke Corporation (jointly owned by Republic Steel Corporation and Hanna Furnace Corporation, a subsidiary of National Steel Corporation)	Buffalo, New York
Eastern Gas and Fuel Associates	
Eastern Associated Coal Corp., subsidiary	Philadelphia, Pennsylvania
Empire Coke Company	Holt, Alabama
Ford Motor Company	
Steel Division	Rouge, Michigan
Great Lakes Carbon Corporation	
Missouri Coke and Chemical Division	St. Louis, Missouri
Indiana Gas & Chemical Corporation	Terre Haute, Indiana
Inland Steel Company	Indiana Harbor, Indiana
Interlake, Inc.	South Chicago, Illinois Toledo, Ohio

Table 10-6 (Continued)

Company	Location
International Harvestor Company	
Wisconsin Steel Division	South Chicago, Illinois
Jones & Laughlin Industries, Inc.	
(owned by the LTV Corporation) Jones & Laughlin Steel Corp., subsidiary	Aliquippa, Pennsylvania Pittsburgh, Pennsylvania
Kaiser Steel Corporation	Fontana, California
Koppers Company, Inc.	
Organic Material Division	Erie, Pennsylvania St. Paul, Minnesota Woodward, Alabama
Lykes Corporation	
Youngstown Sheet and Tube Company, subsidiary	Campbell, Ohio Indiana Harbor, Indiana
McClouth Steel Corporation*	Ironton, Ohio
Milwaukee Solvay Coke Company	
(affiliated with Pickands Mather & Co., subsidiary of Moore and McCormick Co., Inc.)	Milwaukee, Wisconsin
National Steel Corporation	
Granite City Steel Division	Granite City, Illinois
Great Lakes Steel Division B. F. Division	Zug Island, Michigan
Weirton Steel Division	Weirton, West Virginia
Northwest Industries, Inc.	
Lone Star Steel Company, subsidiary	Daingerfield, Texas
NVF Company	
Sharon Steel Corporation, subsidiary	Fairmont, West Virginia
Republic Steel Corporation	
Iron and Chemical Division	Chicago, Illinois Cleveland, Ohio Gadsden, Alabama Massillon, Ohio Thomas, Alabama Warren, Ohio Youngstown, Ohio

*McClouth Steel Corporation purchased only the coking operations of Allied Chemical Corporation's Ironton, Ohio, facility in 1977. By-products are still manufactured by Allied.

Table 10-6 (Continued)

Company	Location
Shenango Incorporated	
(owned by The Shenango Furnace Company)	Neville Island, Pennsylvania
Tonawanda Coke Corporation	Buffalo, New York
United States Steel Corporation	
USS Agri-Chemicals Division and USS Chemicals Division	Clairton, Pennsylvania Duluth, Minnesota Fairfield, Alabama Fairless Hills, Pennsylvania Gary, Indiana Geneva, Utah Lorain, Ohio
Jim Walter Corporation	
Jim Walter Resources, Inc., subsidiary	
Chemical Division	Birmingham, Alabama
Wheeling-Pittsburgh Steel Corporation	East Steubenville, West Virginia Monessen, Pennsylvania

*See ref. 6.

Table 10-7. Cresols Production and End-Use Emission Factors

Source	lb Lost per lb Produced (Used)				Derivation[a]
	Process	Storage	Fugitive	Total	
Mixed cresol production	0.00190	0.00020	0.00040	0.00250	B[b]
Cresylic acid production	0.00190	0.00020	0.00040	0.00250	B[b]
p-Cresol production	0.0039	0.00030	0.00080	0.00500	D
BHT/antioxidants	0.0008	0.0001	0.0001	0.001	D
Phenolic resins	0.00400	0.0005	0.0005	0.00500	D
Pesticides	0.00040	0.00005	0.00005	0.00050	D
Pyrethroid pesticides	0.00040	0.00005	0.00005	0.00050	C[c]
TCP production	0.00035	0.00005	0.00010	0.0005	D
Miscellaneous, other				0.001[d]	C[b]

[a] Basis: A - site visit data
B - state files
C - published data
D - Hydroscience estimate

[b] See ref. 7.

[c] See ref. 8.

[d] Based on a weighted average of all of cresol uses.

Table 10-8. Cresol Emissions from Mixed Cresol, Cresylic Acid Producers

Company	Location	Emissions (lb/yr)			Total Cresol Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
		Mixed Cresols Producers				
Continental Oil	Newark, NJ	11,400	6,400	2,400	15,000	0.22
Fallek	Tuscaloosa, AL	3,800	400	800	5,000	0.07
Ferro	Santa Fe Springs, CA	7,600	800	1,600	10,000	0.14
Koppers	Oil City, PA	7,600	800	1,600	10,000	0.14
Merichem	Houston, TX	22,800	2,400	4,800	30,000	0.43
Stimson	Anacortes, WA	7,600	800	1,600	10,000	0.14
Total		60,800	6,400	12,800	80,000	
		Cresylic Acid Producers				
Continental Oil	Newark, NJ	17,100	1,800	3,600	22,500	0.32
Crowley Tar Products	Houston, TX	9,500	1,000	2,000	12,500	0.18
Fallek	Tuscaloosa, AL	5,700	600	1,200	7,500	0.11
Ferro	Santa Fe Springs, CA	9,500	1,000	2,000	12,500	0.18
Koppers	Follansbee, WV	11,400	1,200	2,400	15,000	0.22
Merichem	Houston, TX	32,300	3,400	6,800	42,500	0.61
Mobil Oil	Beaumont, TX	3,800	400	800	5,000	0.07
Stimson Lumber	Anacortes, WA	9,500	1,000	2,000	12,500	0.18
Total		98,800	10,400	20,800	130,000	

*Based on 8760 hr/yr operation.

Total cresylic acid production emissions were estimated to have been 130,000 lb. Of this total 3,900 lb were o-cresol, 45,500 lb were p-cresol, and 44,200 lb were m-cresol.

Since both mixed cresols and cresylic acid share common producing sites, and in the absence of other emission data, the same emission factor of 0.00250 was used to estimate emissions for both. It was assumed that the cresol isomer composition in the emissions was the same as in the product mixtures shown in Table 10-3.

Process vent emissions originate primarily from distillation and neutralizaton processes. Storage emissions represent the losses from both working and final product storage as well as loading and handling. Fugitive emissions are those which result from plant equipment leaks.

Emissions from the individual isomer production are shown in Table 10-9. The emission factor used for m- and o-cresol production losses is the same that was used for mixed cresols. The p-cresol emission factor used was 0.005 lb/lb since it is synthetically manufactured.

Emissions from o-cresol, p-cresol, and m-cresol individual isomer production were estimated to have been 75,000 lb, 105,000 lb, and 3,750 lb respectively.

B. USES

The emissions from specific end-user locations are shown in Table 10-10 for p-cresol isomer used in BHT production, m-cresol isomer used in pyrethroid pesticide production, and mixed cresols/cresylic acid used in TCP production Emission estimates were developed using the emission factors shown in Table 10-7.

o-Cresol emissions from BHT production were 15,000 lb. Emissions resulting from its use in antioxidant manufacture were estimated to be 10,000 lb. Specific manufactures and locations for regional distribution of antioxidant emissions were not available.

Emissions from m-cresol use were estimated to have been 750 lb. Emissions were distributed evenly over all three sites in the absence of capacity data.

Table 10-9. **Cresol Isomer Emissions from Cresol Isomer Producers**

Company	Location	Emissions (lb/yr) Process	Emissions (lb/yr) Storage	Emissions (lb/yr) Fugitive	Total Emissions (lb/yr)	Total Emissions (g/sec)*
		o-Cresol Producers				
Continental Oil	Newark, NJ	9,500	1,000	2,000	12,500	0.18
Fallek	Tuscaloosa, AL	11,400	1,200	2,400	15,000	0.22
Ferro	Santa Fe Springs, CA	5,700	600	1,200	7,500	0.11
Koppers	Oil City, PA	5,700	600	1,200	7,500	0.11
Merichem	Houston, TX	19,000	2,000	4,000	25,000	0.36
Stimson	Anacortes, WA	5,700	600	1,200	7,500	0.11
Total		57,000	6,000	12,000	75,000	
		p-Cresol Producer				
Sherwin-Williams	Chicago, IL	81,900	6,300	16,800	105,000	1.51
Total		81,900	6,300	16,800	105,000	
		m-Cresol Producers				
Koppers	Oil City, PA	1,425	150	300	1,875	0.03
Merichem	Houston, TX	1,425	150	300	1,875	0.03
Total		2,850	300	600	3,750	

*Based on 8760 hr/yr operation.

Table 10-10. Cresol Emissions from Cresol Users

		Emissions (lb/yr)			Total Emissions	
Company	Location	Process	Storage	Fugitive	(lb/yr)	(g/sec)*
		o-Cresol Isomer				
2,6-Di-tert-buty-p-cresol (BHT) producers						
Ashland	Fords, NJ	4,000	500	500	5,000	0.07
Koppers	Oil City, PA	3,200	400	400	4,000	0.06
Shell	Martinez, CA	3,200	400	400	4,000	0.06
Uniroyal	Geismar, LA	1,600	200	200	2,000	0.03
Total		12,000	1,500	1,500	15,000	
		m-Cresol Isomer				
Pyrethroid pesticide producers						
CPC International	Lyndhurst, NJ	200	25	25	250	0.004
FMC	Baltimore, MD	200	25	25	250	0.004
Vertac	West Helena, AR	200	25	25	250	0.004
Total		600	75	75	750	
		Mixed Cresols/Cresylic Acid				
Tricresyl phosphate/cresyl diphenylphosphate producers						
FMC	Nitro, WV	7,000	1,000	2,000	10,000	0.14
Stauffer	Gallipolis Ferry, WV	5,500	550	1,100	5,500	0.08
Total		12,500	1,550	3,100	15,500	

*Based on 8760 hr/yr operation.

Emissions from the use of cresols/cresylic acid to manufacture TCP were estimated to have been 15,500 lb. Of that total 2120 lb were o-cresol, 4900 lb were p-cresol, and 5800 lb were m-cresol.

Other sources of cresol emissions had to be handled on a regional basis because of their widespread use.

Emissions of p-cresol isomer and cresol/cresylic acid used to produce phenolic resins are summarized in Table 10-11 by geographic region. Emissions from this end-use were estimated to have been 13,700 lb o-cresol, 37,400 lb m-cresol, and 31,600 lb p-cresol. In addition, 27,500 lb of p-cresol was lost when used as an individual isomer for phenolic resins production. Total emissions of all isomers were distributed based on the number of sites in each region.

The emissions of p-cresol isomer and cresol/cresylic acid used to produce pesticides are shown in Table 10-12 by geographic region. Emissions from this end-use were estimated to have been 1265 lb p-cresol, 550 lb o-cresol, and 2185 lb m-cresol from cresol/cresylic acid use. In addition, 2500 lb p-cresol was lost from its use as an individual isomer in pesticide production. Total emissions were distributed by the number of sites in each region.

The emissions of cresols in wire enamel solvents are shown in Table 10-13. Emissions were developed by assuming that all cresols used in this solvent application are lost and that the emission composition of cresol isomers is the same as the end-use production shown in Table 10-3. Emissions were estimated to have been 2,740,000 lb o-cresol, 6,320,000 pcresol, and 7,480,000 m-cresol. Emissions were distributed over the number of paint and lacquer sites in the U.S. in the absence on any other distributable data.

Emissions from cresols/cresylic acid used in ore flotation were estimated to have been 411,000 lb o-cresol, 1,122,000 lb m-cresol, and 948,000 p-cresol in 1978. Emissions are summarized and distributed in Table 10-14 by the number of mining sites in the U.S.

Emissions from coke ovens were estimated to have been 796,080 lb o-cresol, 1,104,240 lb m-cresol, and 667,680 lb p-cresol in 1978. Emissions were

Table 10-11. Cresol Isomer Emissions from Phenolic Resin Producers by Region[a]

Region	Number of Sites	o-Cresol Emissions (lb/yr)	p-Cresol Emissions From Isomer (lb/yr)	p-Cresol Emissions From Cresols/ Cresylic Acid (lb/yr)	m-Cresol Emissions (lb/yr)
New England	6	660	1,320	1,500	1,800
Middle Atlantic	26	2,860	5,720	6,500	7,800
East North Central	31	3,410	6,820	7,750	9,300
West North Central	5	550	1,100	1,250	1,500
South Atlantic	15	1,650	3,300	3,750	4,500
East South Central	6	660	1,320	1,500	1,800
West South Central	11	1,210	2,420	2,750	3,300
Mountain	1	110	220	250	300
Pacific	24	2,640	5,280	6,000	7,200
Total	125	13,700[b]	27,500[c]	31,600[d]	37,400[e]

[a] See ref. 9.

[b] Average 110 lb/yr per site.

[c] Average 220 lb/yr per site.

[d] Average 250 lb/yr per site.

[e] Average 300 lb/yr per site.

Table 10-12. 1978 Cresol Isomer Emission Estimates from Pesticide Manufacturers[a]

Region	Number of Sites	p-Cresol As Isomer (lb/yr)	p-Cresol In Mixed Cresols/ Cresylic Acid (lb/yr)	o-Cresol in Mixed Cresols/ Cresylic Acid (lb/yr)	m-Cresol in Mixed Cresols/ Cresylic Acid (lb/yr)
New England	4	72	36	16	63
Middle Atlantic	37	666	337	148	581
East North Central	19	342	173	76	298
West North Central	15	270	137	60	236
South Atlantic	17	306	155	68	267
East South Central	14	250	127	56	220
West South Central	15	270	137	60	236
Mountain	5	90	46	20	79
Pacific	13	234	118	52	204
Total	139	2500[b]	1265[c]	550[d]	2185[e]

[a] See ref. 10.

[b] Average 18 lb/yr per site.

[c] Average 9.1 lb/yr per site.

[d] Average 4.0 lb/yr per site.

[e] Average 15.7 lb/yr per site.

Table 10-13. Cresol Isomer Emissions from Mixed Cresols/Cresylic Acid Used as Wire Enamel Solvent[a]

Region	Number of Sites	o-Cresol Emissions (lb/yr)	p-Cresol Emissions (lb/yr)	m-Cresol Emissions (lb/yr)
New England	46	79,975	184,465	218,325
Middle Atlantic	339	589,380	1,359,440	1,608,960
East North Central	370	643,275	1,483,755	1,756,090
West North Central	84	146,040	336,855	398,680
South Atlantic	174	302,510	697,765	825,835
East South Central	44	76,500	176,445	208,830
West South Central	87	151,255	348,885	412,920
Mountain	258	448,555	1,034,620	1,224,520
Pacific	174	302,510	697,765	825,840
Total	1,576	2,740,000	6,320,000	7,480,000

[a] See ref. 11.

[b] Average 1738.6 lb/yr per site.

[c] Average 4010.2 lb/yr per site.

[d] Average 4746.2 lb/yr per site.

Table 10-14. Cresol Isomer Emissions from Mixed Cresol/Cresylic Acid Used as an Ore Flotation Agent[a]

Region	Number of (Mining) Sites	o-Cresol Emissions (lb/yr)	m-Cresol Emissions (lb/yr)	p-Cresol Emissions (lb/yr)
New England	6	4,382	11,957	10,103
Middle Atlantic	38	27,750	75,729	63,987
East North Central	85	62,075	169,392	143,128
West North Central	145	105,890	288,964	244,159
South Atlantic	62	45,275	123,557	104,399
East South Central	40	29,211	79,714	67,354
West South Central	21	15,336	41,850	35,361
Mountain	144	105,161	286,971	242,475
Pacific	22	16,066	43,843	37,045
Total	563	411,000[b]	1,122,000[c]	984,000[d]

[a] See ref. 12.

[b] Average 730 lb/yr per site

[c] Average 1993 lb/yr per site.

[d] Average 1684 lb/yr per site.

estimated by assuming that for 107 billion lb coke produced, 0.000024 lb of cresols would be lost per pound of coke produced. Composition of the cresols is the same as the mixed cresols product composition shown in Table 10-3. Emissions are summarized and distributed in Table 10-15 by the number of coke oven sites in each region.

Emissions from the solvent use of cresols/cresylic acid as a disinfectant/cleaning compound were estimated to have been 411,000 lb o-cresol, 948,000 lb p-cresol, and 1,122,000 m-cresol. Emissions are considered widespread in proportion with population.

Miscellaneous uses as a chemical intermediate are too widespread to allow for regional distribution. Emission estimates were made by using a weighted average emission factor of 0.001 lb lost/lb use derived from all other isomers, mixed cresols, and cresylic acid end-users. Emissions from miscellaneous uses were estimated to have been 1000 lb o-cresol, 2200 lb p-cresol, and 2600 lb m-cresol.

Vent parameter data for both production and end-uses of cresols are summarized in Table 10-16.

The total nationwide emissions of o-cresol, p-cresol, and m-cresol are estimated to have been 4,504,150 lb, 9,124,945 lb, and 10 959,325 lb respectively. Total emissions are summarized in Tables 10-17, 10-18, and 10-19 for o-cresol, p-cresol and m-cresol, respectively.

Table 10-15. Cresol Isomer Emissions from Coke Oven Operations[a,b]

Region	Number of Sites	o-Cresol Emissions (lb/yr)	m-Cresol Emissions (lb/yr)	p-Cresol Emissions (lb/yr)	Total Cresol Emissions (lb/yr)
New England	0	0	0	0	0
Middle Atlantic	15	195,750	271,500	164,175	631,500
East North Central	25	326,250	452,500	273,625	1,052,500
West North Central	3	39,150	54,300	32,835	126,300
South Atlantic	4	52,200	72,400	43,780	168,400
East South Central	9	117,450	162,900	98,505	378,900
West South Central	2	26,100	36,200	21,890	84,200
Mountain	2	26,100	36,200	21,890	84,200
Pacific	1	13,050	18,100	10,945	42,100
Total	61	796,080[c]	1,104,240[d]	667,680[e]	2,568,000

[a] See ref. 6.

[b] Basis: 107 billion lb coke produced; 0.000024 lb cresols emitted/lb coke produced; cresol composition - 26% p-cresol, 31% o-cresol, and 43% m-cresol in mixed cresols emitted.

[c] Average 13,050 lb/yr per site.

[d] Average 18,100 lb/yr per site.

[e] Average 10,945 lb/yr per site.

Table 10-16. Cresol Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Discharge Area (ft X ft)
Production (all types)						
Process	2	30	1	208	75	
Storage	8	24	0.17	80		
Fugitive						300 X 600
BHT/TCP production						
Process	1	60	0.5	150	35	
Storage	4	16	0.17	80		
Fugitive						100 X 100
Phenolic resins						
Process	1	60	0.33	150	20	
Storage	1	16	0.17	80		
Fugitive						100 X 100
Pesticides/pyrethroids						
Process	1	30	0.17	100	15	
Storage	2	20	0.17	80		
Fugitive						100 X 100
Wire enamel solvent						
Process	1	40	0.25	120	10	
Ore flotation						
Process	1	20	0.25	120	10	

Building cross-section: Production - 200 m^2; BHT/TCP - 100 m^2; Phenolic Resins - 50 m^2; Pesticides - 100 m^2; Wire Enamel Solvent 0 200 m^2; Ore Flotation - 50 m^2.

Table 10-17. 1978 Nationwide o-Cresol Emissions

Source	Nationwide Emissions (lb/yr)
o-Cresol production	75,000
Mixed cresol production	24,800
Cresylic acid production	3,900
BHT production	15,000
Antioxidants production	10,000
Tricresyl phosphate production	2,120
Phenolic resins	13,700
Wire enamel solvent	2,740,000
Pesticides	550
Disinfectants/cleaning compounds	411,000
Ore flotation agent	411,000
Miscellaneous, other	1,000
Coke ovens	796,080
Total	4,504,150

Table 10-18. 1978 Nationwide p-Cresol Emissions

Source	Nationwide Emissions (lb/yr)
p-Cresol production	105,000
Mixed cresol production	20,800
Cresylic acid production	45,500
Phenolic resins production (isomer)	27,500
Pesticides production	2,500
Tricresyl phosphate	4,900
Phenolic resins	31,600
Wire enamel solvent	6,320,000
Pesticides	1,265
Disinfectants/cleaning compounds	948,000
Ore flotation agent	948,000
Miscellaneous, other	2,200
Coke ovens	667,680
Total	9,124,945

Table 10-19. 1978 Nationwide Emissions m-Cresol

Source	Nationwide Emissions (lb/yr)
m-Cresol production	3,750
Mixed cresol production	34,400
Cresylic acid production	44,200
Pyrethroid pesticide	750
Tricresyl phosphate	5,800
Phenolic resins	37,400
Wire enamel solvent	7,480,000
Pesticides	2,185
Disinfectants/cleaning compounds	1,122,000
Ore flotation agent	1,122,000
Miscellaneous, other	2,600
Coke ovens	1,104,240
Total	10,959,325

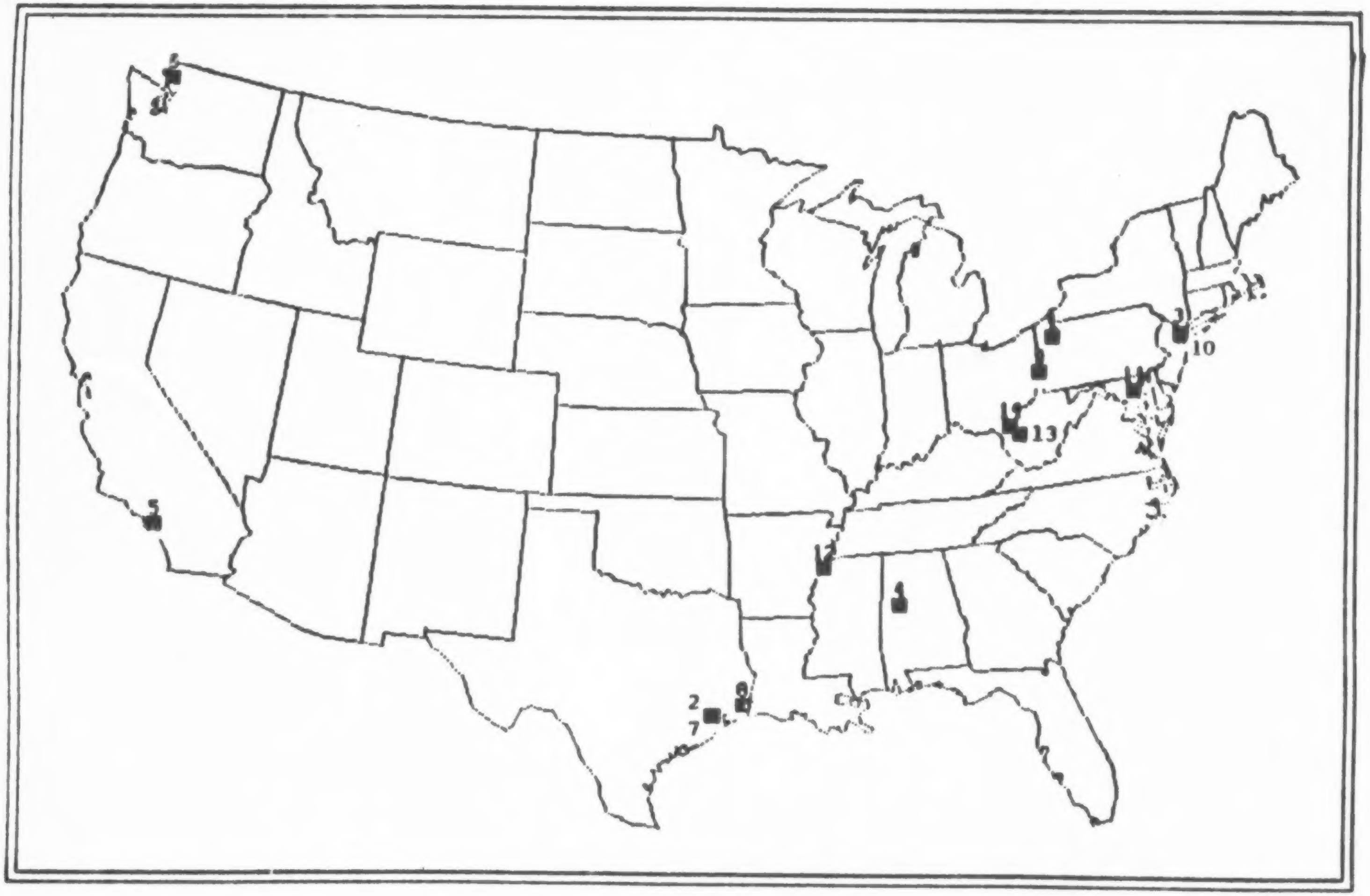


FIGURE 10-1. SPECIFIC POINT SOURCES OF m-CRESOL EMISSIONS.

TABLE 10-20. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF m-CRESOL

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	KOPPERS	OIL CITY, PA	41 29 30	079 43 20	14860	1	1 2	.020520 .047088	.002160 .004896	.004320 .009936
2	MEKICHEM	HOUSTON, TX	29 45 36	095 10 48	12906	2	1 2 3	.020520 .141120 .158112	.002160 .014832 .016704	.004320 .029664 .033264
3	CONTINENTAL OIL	NEWARK, NJ	40 43 34	074 07 26	94741	3	2 3	.070560 .083664	.039600 .008784	.014832 .017568
4	FALLEK	TUSCALOOSA, AL	33 11 00	087 34 50	93806	3	2 3	.023472 .027936	.002448 .002880	.004896 .005904
5	FERRO	SANTA FE S, CA	33 56 30	118 04 18	93106	3	2 3	.047088 .027936	.004896 .002880	.009936 .005904
6	STINSON	ANACORTES, WA	48 28 31	122 32 48	24217	3	2 3	.047088 .046512	.004896 .004896	.009936 .009792
7	CROWLEY TAR	HOUSTON, TX	29 43 50	095 14 20	12906	4	3	.046512	.004396	.009792
8	MOBIL OIL	BEAUMONT, TX	30 04 14	094 03 40	12917	4	3	.158112	.016704	.033264
9	KOPPERS	FOLLANSBEE, WV	40 23 10	080 35 07	14762	4	3	.055872	.005904	.011808
10	CPC	LYNDHURST, NJ	40 47 30	074 04 34	94741	5	4	.002880	.000360	.000360
11	FMC	BALTIMORE, MD	39 14 50	076 35 30	93721	5	4	.002880	.000360	.000360
12	VERTAC	WEST HELENA, AR	34 36 10	090 33 45	13959	5	4	.002880	.000360	.000360
13	FMC	NITRO, WV	38 25 33	081 50 05	13866	6	5	.037728	.005328	.010800
14	STAUFFER	GALLIPOLIS FY, WV	38 46 40	062 10 54	13866	6	5	.029664	.002966	.005904

TABLE 10-20. (Concluded)

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* Plant Types:

Type 1: Plant produces isolated m-cresol and mixed cresols
Type 2: Plant produces isolated m-cresol, mixed cresols, and cresylic acid
Type 3: Plant produces mixed cresols and cresylic acid
Type 4: Plant produces cresylic acid
Type 5: Plant produces pyrethroid pesticide
Type 6: Plant produces tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP)

† Source Types:

Type 1: Isolated m-cresol production
Type 2: Mixed cresols production
Type 3: Cresylic acid production
Type 4: Pyrethroid pesticide production
Type 5: Tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP) production

TABLE 10-21. EXPOSURE AND DOSAGE OF m-CRESOL RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
5	2	10.6
2.5	43	143
1	240	459
0.5	947	979
0.25	3,243	1,760
0.1	17,464	3,850
0.05	40,501	5,460
0.025	111,091	7,840
0.01	508,466	13,800
0.005	1,273,154	19,000
0.0025	3,370,507	26,200
0.001	8,666,629	39,900
0.0005	11,188,566	36,800
3.12×10^{-6}*	21,040,904	37,800

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 10-22. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF m-CRESOL

Region	Resins Production		Wire Enamel Solvent		Pesticide Production		Ore Flotation		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00431	6	0.0683	46	0.000155	4	0.0287	6	0	0
Middle Atlantic	0.00431	26	0.0683	339	0.000155	37	0.0287	38	0.261	15
East North Central	0.00431	31	0.0683	370	0.000155	19	0.0287	85	0.261	25
West North Central	0.00431	5	0.0683	84	0.000155	15	0.0287	145	0.261	3
South Atlantic	0.00431	15	0.0683	174	0.000155	17	0.0287	62	0.261	4
East South Central	0.00431	6	0.0683	44	0.000155	14	0.0287	40	0.261	9
West South Central	0.00431	11	0.0683	87	0.000155	15	0.0287	21	0.261	2
Mountain	0.00431	1	0.0683	258	0.000155	5	0.0287	144	0.261	2
Pacific	0.00431	24	0.0683	174	0.000155	13	0.0287	22	0.261	1

TABLE 10-23. **EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM** GENERAL POINT SOURCES OF m-CRESOL

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)						Dosage [$10^6(\mu g/m^3)$ persons]					
	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total
5.0	0	0	0	0	8.0	8.0	0	0	0	0	0.06	0.06
2.5	0	31	0	0	23	54	0	0.10	0	0	0.10	0.20
1.0	0	287	0	4	73	364	0	0.46	0	0.004	0.19	0.65
0.5	0	815	0	26	199	1,064	0	0.83	0	0.02	0.27	1.12
0.25	0	1,960	0	101	449	2,510	0	1.23	0	0.04	0.35	1.62
0.10	--	--	--	--	--	--	0	1.86	0	0.08	0.52	2.45
0.05	--	--	--	--	--	--	0.002	2.70	0	0.11	0.62	3.43
0.025	--	--	--	--	--	--	0.004	3.32	0	0.14	0.74	4.20
0.01	--	--	--	--	--	--	0.007	4.36	0	0.20	0.91	5.48
0	--	--	--	--	--	--	0.04	8.2	0.002	0.56	1.22	10.0

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 10-24. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF m-CRESOL

Parameter	Value
Daytime decay rate (K_d)	1.68×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	1.0×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	16.20 gm/sec
Cleaning solvent	16.16 gm/sec
Miscellaneous	0.04 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 10-25. m-CRESOL EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.050000	505140	42338.5	0.	100.0	0.	100.0	0.	0.
.025000	9149730	274137.2	0.	100.0	0.	100.0	0.	0.
.010000	23637585	464245.9	0.	100.0	0.	100.0	0.	0.
.005000	51757583	654161.0	0.	100.0	0.	97.8	.7	1.5
.002500	123305988	914669.0	0.	100.0	0.	94.5	2.5	2.9
0.	158679135	973892.7	0.	100.0	0.	91.8	3.0	5.3

TABLE 10-26. EXPOSURE AND DOSAGE SUMMARY OF m-CRESOL

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
5	2	8,000	0	8,000	11	60,000	0	60,000
2.5	43	54,000	0	54,043	143	200,000	0	200,100
1	240	364,000	0	364,240	459	650,000	0	650,500
0.5	947	1,064,000	0	1,064,947	979	1,120,000	0	1,121,000
0.25	3,243	2,510,000	0	2,513,242	1,760	1,620,000	0	1,622,000
0.1	17,464	--	0	--	3,850	2,450,000	0	2,454,000
0.05	40,464	--	505,140	--	5,460	3,430,000	42,339	3,477,000
0.025	111,091	--	9,149,730	--	7,840	4,200,000	274,137	4,482,000
0.01	508,466	--	23,637,585	--	13,800	5,480,000	464,246	5,958,000
0.005	1,273,154	--	51,757,583	--	19,000	--	654,161	--
0.0025	3,370,507	--	123,305,988	--	26,200	--	914,669	--
0.001	8,666,629	--	--	--	34,900	--	--	--
0.0005	11,188,566	--	--	--	36,800	--	--	--
0	21,040,904	--	158,679,135	--	37,800	10,000,000	973,900	11,012,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

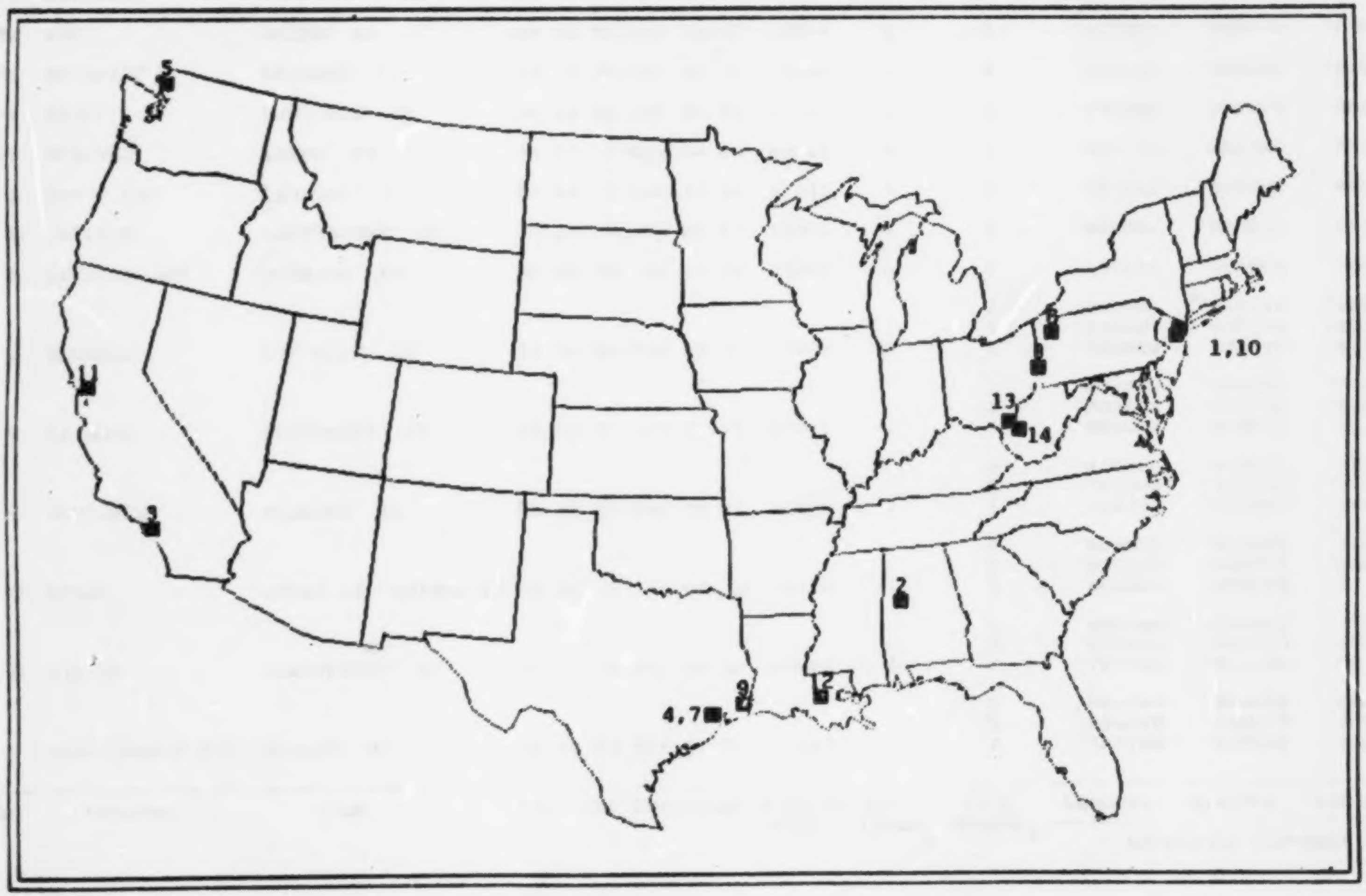
5
11
3
4,7
9
12
2
13
14
6
8
1,10

FIGURE 10-2. SPECIFIC POINT SOURCES OF o-CRESOL EMISSIONS

TABLE 10-27. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF o-CRESOL

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	CONTINENTAL OIL	NEWARK, NJ	40 43 34	074 07 26	94741	1	1	.136000	.014400	.028800
							2	.050832	.028512	.010656
							3	.007344	.000720	.001584
2	FALLEK	TUSCALOOSA, AL	33 11 00	087 34 50	93806	1	1	.164160	.017280	.034560
							2	.016992	.001728	.003456
							3	.002448	.000288	.000576
3	FERRO	SANTE FE SPRINGS,CA	33 56 30	118 04 18	93106	1	1	.082080	.008640	.017280
							2	.033984	.003456	.007200
							3	.004032	.000432	.000864
4	MERICHEM	HOUSTON, TX	29 45 36	095 10 48	12906	1	1	.273600	.028800	.057600
							2	.101088	.010656	.021600
							3	.013968	.001440	.002880
5	STIMSON	ANACORTES, WA	48 28 31	122 32 48	24217	1	1	.082080	.008640	.017280
							2	.033984	.003456	.007200
							3	.004032	.000432	.000864
6	KOPPERS	OIL CITY, PA	41 29 30	079 43 20	14860	2	1	.082080	.008640	.017280
							2	.033984	.003456	.007200
							4	.046080	.005760	.005760
7	CROWLEY TAR	HOUSTON, TX	29 43 50	95 14 20	12906	3	3	.004032	.000864	.000432
8	KOPPERS	FOLLANSBEE, WV	40 23 10	080 35 07	14762	3	3	.004896	.000576	.001008
9	MOBIL OIL	BEAMONT, TX	30 04 14	094 03 40	12917	3	3	.001584	.000144	.000288
10	ASHLAND	FORDS, NJ	40 31 22	074 20 50	04739	4	4	.057600	.007200	.007200
11	SHELL	MARTINEZ, CA	38 00 05	122 06 40	23202	4	4	.046080	.005760	.005760
12	UNIROYAL	GEISMAR, LA	30 13 30	091 00 15	12958	4	4	.023040	.002880	.002880
13	FMC	NITRO, WV	38 25 33	081 50 05	13866	5	5	.013824	.002016	.003888
14	STAUFFER	GALLIPOLIS FY, WV	38 46 40	082 10 54	13841	5	5	.010080	.001080	.002160

TABLE 10-27 (Concluded)

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* Plant Types:

Type 1: Plant produces isolated o-cresol, mixed cresols, and cresylic acid
Type 2: Plant produces isolated o-cresol, mixed cresols, and 2,6-di(t-butyl)-p-cresol (BHT)
Type 3: Plant produces cresylic acid
Type 4: Plant produces 2,6-di(t-butyl)-p-cresol (BHT)
Type 5: Plant produces tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP)

† Source Types:

Type 1: o-Cresol production
Type 2: Mixed cresols production
Type 3: Cresylic acid production
Type 4: 2,6-Di(t-butyl)-p-cresol (BHT) production
Type 5: Tricresyl phosphate (TCP) and cresyl diphonyl phosphate (CDP) production

TABLE 10-28. EXPOSURE AND DOSAGE OF o-CRESOL RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
0.05	70	4.55
0.025	215	9.47
0.01	1,318	26.3
0.005	4,166	51.5
0.0025	7,461	62.6
0.001	25,599	89.3
0.0005	48,734	106
0.00025	116,611	129
0.0001	421,797	176
0.00005	907,944	210
6.96×10^{-6}*	1,336,543	225

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 10-29. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF o-CRESOL

Region	Resins Production Emissions/Site (gm/sec)	Resins Production Number of Sites	Wire Enamel Solvent Emissions/Site (gm/sec)	Wire Enamel Solvent Number of Sites	Pesticide Production Emissions/Site (gm/sec)	Pesticide Production Number of Sites	Ore Flotation Emissions/Site (gm/sec)	Ore Flotation Number of Sites	Coke Oven Emissions/Site (gm/sec)	Coke Oven Number of Sites
New England	0.00158	6	0.0250	46	0.000057	4	0.0105	6	0.188	0
Middle Atlantic	0.00158	26	0.0250	339	0.000057	37	0.0105	38	0.188	15
East North Central	0.00158	31	0.0250	370	0.000057	19	0.0105	85	0.188	25
West North Central	0.00158	5	0.0250	84	0.000057	15	0.0105	145	0.188	3
South Atlantic	0.00158	15	0.0250	174	0.000057	17	0.0105	62	0.188	4
East South Central	0.00158	6	0.0250	44	0.000057	14	0.0105	40	0.188	9
West South Central	0.00158	11	0.0250	87	0.000057	15	0.0105	21	0.188	2
Mountain	0.00158	1	0.0250	258	0.000057	5	0.0105	144	0.188	2
Pacific	0.00158	24	0.0250	174	0.000057	13	0.0105	22	0.188	1

TABLE 10-30. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF o-CRESOL

Concentration Level (µg/m³)	Population Exposed (10³ persons)						Dosage [10³(µg/m³) persons]					
	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total
5.0	0	0	0	0	3	3	0	0	0	0	21	21
2.5	0	0	0	0	14	14	0	0	0	0	59	59
1.0	0	17	0	0	48	65	0	22	0	0	111	133
0.50	0	147	0	0.3	119	266	0	110	0	0.2	160	270
0.25	0	541	0	12	302	854	0	245	0	4	225	474
0.10	0	1,750	0	95	1,040	2,890	0	430	0	16	336	783
0.050	2.6	4,400	0	234	1,990	6,630	0.2	612	0	26	402	1,040
0.025	--	--	--	--	--	--	0.6	830	0	37	507	1,370
0.010	--	--	--	--	--	--	1.4	1,180	0	53	601	1,830
0.005	--	--	--	--	--	--	2	1,480	0	72	692	2,240
0	--	--	--	--	--	--	13.5	3,000	0.6	214	881	4,110

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 10-31. **MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF o-CRESOL**

Parameter	Value
Daytime decay rate (K_d)	1.41×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	1.0×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	6.076 gm/sec
Cleaning solvent	5.918 gm/sec
Antioxidants production	0.144 gm/sec
Miscellaneous	0.014 gm/sec
National mobile source emissions	0

TABLE 10-32. o-CRESOL EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.025000	505146	15955.3	0.	100.0	0.	100.0	0.	0.
.010000	9149780	105758.2	0.	100.0	0.	100.0	0.	0.
.005000	17851646	152043.0	0.	100.0	0.	100.0	0.	0.
.002500	40810878	228922.1	0.	100.0	0.	99.0	.2	.8
.001000	119506114	340564.9	0.	100.0	0.	94.7	2.4	2.9
.000500	151204808	372500.6	0.	100.0	0.	92.4	2.9	4.7
0.	158679135	374759.0	0.	100.0	0.	91.9	2.9	5.2

TABLE 10-33. EXPOSURE AND DOSAGE SUMMARY OF o-CRESOL

	Population Exposed (persons)				Dosage [(µg/m³)·persons]			
Concentration Level (µg/m³)	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
5	0	3,000	0	3,000	0	21,000	0	21,000
2.5	0	14,000	0	14,000	0	59,000	0	59,000
1	0	65,000	0	65,000	0	133,000	0	133,000
0.5	0	266,000	0	266,000	0	270,000	0	270,000
0.25	0	854,000	0	854,000	0	474,000	0	474,000
0.1	0	2,890,000	0	2,890,000	0	783,000	0	783,000
0.05	70	6,630,000	0	6,630,070	5	1,040,000	0	1,040,005
0.025	215	--	505,140	--	9	1,370,000	15,955	1,385,964
0.01	1,318	--	9,149,730	--	26	1,830,000	105,758	1,935,784
0.005	4,166	--	17,551,646	--	52	2,240,000	152,043	2,392,095
0	1,336,543	--	158,679,135	--	225	4,110,000	374,759	4,485,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

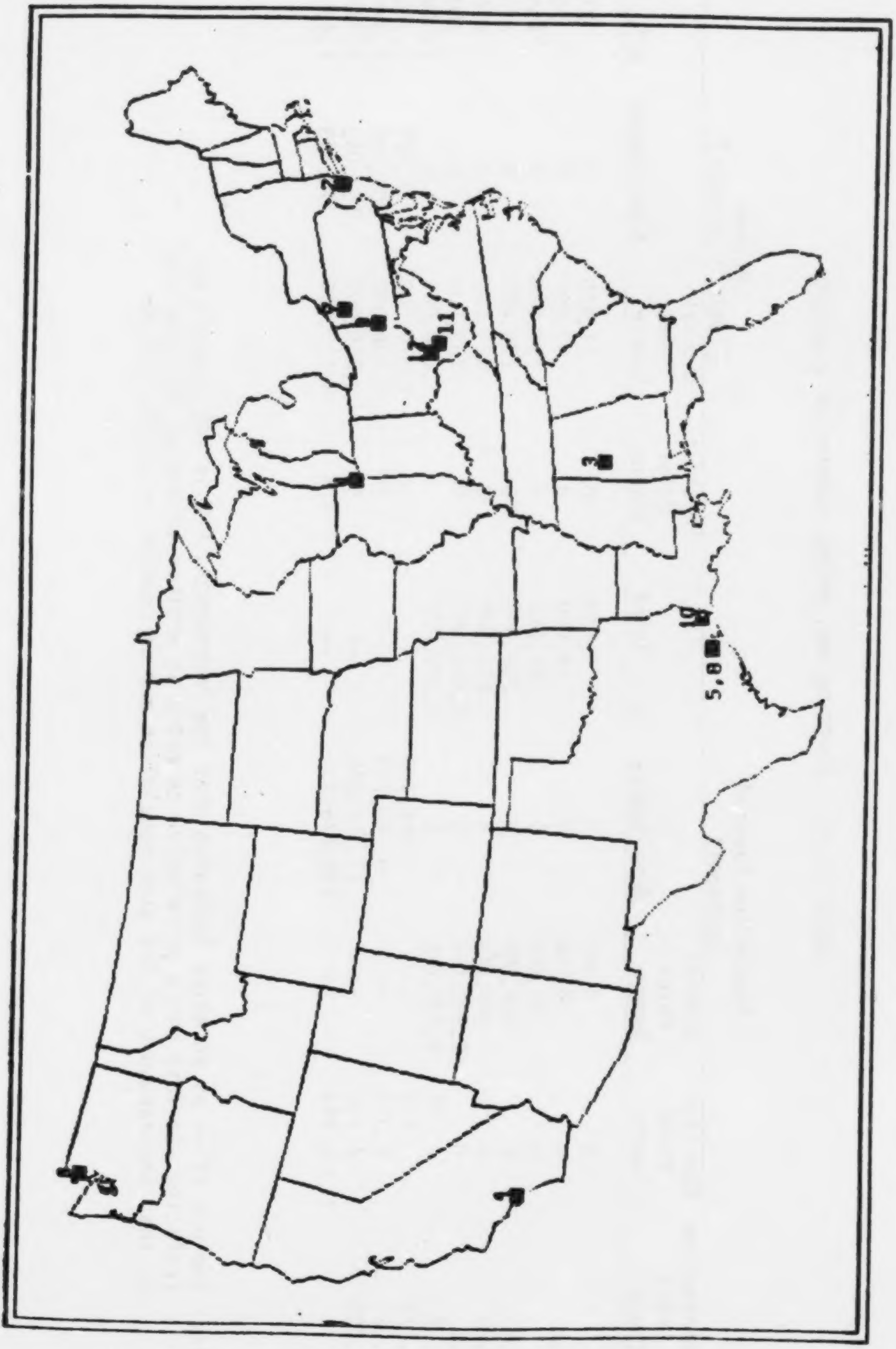

FIGURE 10-3. SPECIFIC POINT SOURCES OF p-CRESOL EMISSIONS

TABLE 10-34. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF p-CRESOL

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	SHERWIN-WILLIAM	CHICAGO, IL	41 43 04	087 36 30	94846	1	1	1.179360	.090720	.241920
2	CONTINENTAL OIL	NEWARK, NJ	40 43 34	074 07 26	94741	2	2 3	.042624 .086256	.023904 .009072	.008928 .018144
3	FALLEK	TUSCALOOSA, AL	33 11 00	087 34 50	93806	2	2 3	.014256 .028800	.001440 .003024	.003024 .006048
4	FERRO	SANTA FE S, CA	33 56 30	118 04 18	93166	2	2 3	.028512 .046368	.003024 .005040	.006048 .010080
5	MERICHEM	HOUSTON, TX	29 45 36	095 10 48	12906	2	2 3	.085392 .162720	.008928 .017136	.018000 .034272
6	STIMSON	ANACORTEX, WA	48 28 31	122 32 48	24217	2	2 3	.028512 .046368	.003024 .005040	.003456 .005040
7	KOPPERS	OIL CITY, PA	41 29 30	079 43 20	14860	3	2	.028512	.003024	.006048
8	CROWLEY TAR	HOUSTON, TX	29 43 50	095 14 20	12906	4	3	.047808	.005040	.010080
9	KOPPERS	FOLLANSBEE, WV	40 23 10	080 35 07	14762	4	3	.057456	.006048	.012096
10	MOBIL OIL	BEAUMOUNT, TX	30 04 14	094 03 40	12917	4	3	.019152	.002016	.004032
11	FMC	NITRO, WV	38 25 33	081 50 05	13866	5	4	.031824	.004608	.009072
12	STAUFFER	GALLIPOLIS FY, WV	38 46 40	082 10 54	13866	5	4	.025056	.002448	.005040

TABLE 10-34. (Concluded)

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* Plant Types:

Type 1: Plant produces isolated p-cresol
Type 2: Plant produces mixed cresols and cresylic acid
Type 3: Plant produces mixed cresols
Type 4: Plant produces cresylic acid
Type 5: Plant produces tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP)

† Source Types:

Type 1: p-cresol production
Type 2: Mixed cresols production
Type 3: Cresylic acid production
Type 4: Tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP) production

TABLE 10-35. EXPOSURE AND DOSAGE OF p-CRESOL RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
5	227	1,460
2.5	1,116	4,450
1	5,358	10,500
0.5	16,508	18,500
0.25	40,620	26,700
0.1	170,926	46,300
0.05	419,077	63,100
0.025	891,820	79,500
0.01	1,795,513	93,600
0.005	3,029,719	102,000
0.0025	5,046,244	109,000
0.001	10,304,456	118,000
3.67×10^{-5}*	14,974,476	121,000

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 10-36. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF p-CRESOL

Region	Resins Production		Wire Enamel Solvent		Pesticide Production		Ore Flotation		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of-Sites
New England	0.00681	6	0.0577	46	0.00039	4	0.0242	6	0.158	0
Middle Atlantic	0.00681	26	0.0577	339	0.00039	37	0.0242	38	0.158	15
East North Central	0.00681	31	0.0577	370	0.00039	19	0.0242	85	0.158	25
West North Central	0.00681	5	0.0577	84	0.00039	15	0.0242	145	0.158	3
South Atlantic	0.00681	15	0.0577	174	0.00039	17	0.0242	62	0.158	4
East South Central	0.00681	6	0.0577	44	0.00039	14	0.0242	40	0.158	9
West South Central	0.00681	11	0.0577	87	0.00039	15	0.0242	21	0.158	2
Mountain	0.00681	1	0.0577	258	0.00039	5	0.0242	144	0.158	2
Pacific	0.00681	24	0.0577	174	0.00039	13	0.0242	22	0.158	1

TABLE 10-37. **EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM** GENERAL POINT SOURCES OF p-CRESOL

Concentration Level (μg/m^3)	Population Exposed (10^3 persons)						Dosage [10^3(μg/m^3) persons]					
	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total
5.0	0	0	0	0	2	2	0	0	0	0	12	12
2.5	0	15	0	0	11	26	0	44	0	0	43	87
1.0	0	195	0	2	40	237	0	306	0	2	86	394
0.50	0	688	0	19	99	807	0	643	0	13	126	782
0.25	1.3	1,660	0	77	232	1,970	0.4	971	0	33	173	1,180
0.10	18	5,040	0	280	942	6,280	3	1,480	0	65	273	1,830
0.050	--	--	--	--	--	--	6	2,060	0	88	326	2,480
0.025	--	--	--	--	--	--	8	2,640	0	120	406	3,180
0.010	--	--	--	--	--	--	13	3,590	0.1	173	483	4,260
0	--	--	--	--	--	--	58	6,930	4	493	740	8,230

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 10-38. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF p-CRESOL

Parameter	Value
Daytime decay rate (K_d)	1.41×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	1.0×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	13.683 gm/sec
Cleaning solvent	13.651 gm/sec
Miscellaneous	0.032 gm/sec
National mobile source emissions (E_M)	0

TABLE 10-39. p-CRESOL EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.050000	505140	35930.9	0.	100.0	0.	100.0	0.	0.
.025000	505140	35930.9	0.	100.0	0.	100.0	0.	0.
.010000	19790740	366437.1	0.	100.0	0.	100.0	0.	0.
.005000	44443179	533543.4	0.	100.0	0.	98.0	.4	1.6
.002500	111931566	766690.9	0.	100.0	0.	95.3	2.2	2.5
.001000	151902934	839614.3	0.	100.0	0.	92.3	2.9	4.8
0.	158679135	843949.7	0.	100.0	0.	91.9	2.9	5.2

TABLE 10-40. EXPOSURE AND DOSAGE SUMMARY OF p-CRESOL

Concentration Level (μg/m^3)	Population Exposed (persons)				Dosage [(μg/m^3)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
5	227	2,000	0	2,227	1,460	12,000	0	13,460
2.5	1,116	26,000	0	27,116	4,450	87,000	0	91,450
1	5,358	237,000	0	242,358	10,500	394,000	0	404,500
0.5	16,508	807,000	0	223,508	18,500	782,000	0	800,500
0.25	40,620	1,970,000	0	2,010,620	26,700	1,180,000	0	1,206,700
0.1	170,926	6,280,000	0	6,450,926	46,300	1,830,000	0	1,876,300
0.05	419,077	--	505,140	--	63,100	2,480,000	35,931	--
0.025	891,820	--	505,140	--	79,500	3,180,000	35,931	--
0.01	1,795,513	--	19,790,740	--	93,600	4,260,000	366,437	--
0.005	3,029,719	--	44,443,179	--	102,000	--	533,543	--
0.0025	5,029,719	--	111,931,566	--	109,000	--	766,691	--
0.001	10,304,456	--	151,902,934	--	118,000	--	839,614	--
0	14,974,476	--	158,679,135	--	121,000	8,230,000	843,950	9,185,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. "Cresols and Cresylic Acid," p. 637.5030A—K, Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (May 1979).

2. Kirk-Othmer, Volume 6, 2d ed., pp. 440—442.

3. J. Gosdar, "Air Pollution Assessment of Cresols," Mitre Corp., Report No. MTR-7227, June 1976.

4. "Chemical Products Synopsis on Cresols and Cresylic Acids," Mannsville Chemical Products, Mannsville, New York, August 1977.

5. The 1978 Directory of Chemical Producers, United States, Stanford Research Institute, Menlo Park, CA.

6. "Coke-Oven Plants in the United States," Coal and Coke Products, Chemical Economics Handbook, p. 212.2000A, Stanford Research Institute, Menlo Park, CA (October 1978).

7. New Jersey State Air Files, Continental Oil Co., Newark, NJ, March 31, 1977.

8. Special Project Report "Petrochemical Plant Sites" prepared for Industrial Pollution Control Division, Industrial Environmental Research Laboratory, Environmental Protection Agency, Cincinnati, Ohio, by Monsanto Research Corporation, Dayton, Ohio, April 1976.

9. "Phenolic Resins," p. 580.0933, Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (May 1978).

10. Source Assessment, Pesticide Manufacturing Air Emissions——Overview and Prioritization, Environmental Protection Agency Technology Series, EPA 600/2-78-0049, March 1978.

11. U.S. Bureau of Census, Standard Industrial Code 2851, Paints and Allied Products, 1972.

12. "Industrial Explosives," p. 530.2000B, Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (May 1976).